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Air Pollutant Control Techniques for Crushed and Broken Stone Industry

PEDCo-Environmental, Inc. Cincinnati, OH

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Environmental Protection Agency
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Air pollutant control technologies for the control of particulate emissions from crushed and broken stone production facilities are evaluated. Specific control technologies considered include the use of local ventilation followed by fabric filter collection and wet dust suppression techniques. Performance data based on mass particulate measurements and visual observations are presented. In addition, the capital and annualized emission control costs for several model plant sizes are estimated. The environmental and energy impacts associated with each control technology evaluated are also presented. Alternative regulatory options available are identified and evaluated in terms of their enforceability, impact on the environment, cost and impact on energy.

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1.0 INTRODUCTION

This document presents information on the emission of particulates and their control at crushed and broken stone facilities. Emissions from both process sources and fugitive dust sources are considered. Applicable control techniques are identified and discussed in terms of performance, environmental impacts, energy requirements, and cost. In addition, regulatory formats for limiting particulate emissions from crushed and broken stone facilities are identified and discussed.

1.1 NEED TO REGULATE

The term crushed and broken stone pertains to rock which has been mined from naturally occurring mineral deposits, reduced in size and graded to meet a variety of basic consumer needs. The crushed stone industry is the largest non-fuel, nonmetallic mineral industry in the United States with respect to both total volume and value of production. Total production in 1975 was 818 Tg (901 million tons), valued at over 2.02 billion dollars.[1] The industry is geographically highly dispersed with all States, except Delaware, reporting production. In general, stone production by individual States is proportional to population and industrial activity. The industry is also highly diverse in terms of unit production capacities, rock types processed, and end product uses.

In 1975, there were approximately 5,400 active quarries in the United States located in urban, suburban, and rural areas. Production at these quarries ranged from less than 23,000 Mg (25,000 tons) to several million megagrams per year. Rock mined at these quarries is reduced to stone and graded into products by a number of component process operations integrated into a crushed stone plant. Plants may be either stationary or portable and range in capacity from less than 90 Mg (100 tons) to several thousand megagrams per hour.

Major rock types processed include limestone, which accounted for 74 percent of the total production of stone in 1975; granite (10 percent); trap rock (9 percent); and sandstone (3 percent). Important end products include construction-related materials such as specified and unspecified construction aggregates and roadstone, concrete aggregate, cement, and bituminous aggregate. These, along with other construction-related products, accounted for over 80 percent of the total production of stone in 1975. Other important end uses include agricultural limestone, lime manufacturing, riprap and jetty stone, metallurgical flux, and railroad ballast.

The conversion of naturally occuring rock into crushed and broken stone products involves a series of distinct yet interdependent physical operations. These include both quarrying or mining operations (drilling, blasting, loading, and hauling) and plant process operations (crushing, screening, conveying, and other material handling and transfer operations). All are potentially significant sources of particulate emissions. In a study performed by the Argonne National Laboratory for EPA in April 1975, the crushed stone industry was ranked third highest among the nation's 56 largest particulate source categories.[2]

Estimates developed by EPA for uncontrolled plant process operations indicate that plant process facilities alone (i.e., excluding quarrying and other fugitive dust sources) may emit up to 5.5 kg of dust per megagram of crushed stone produced (11 lbs per ton), or 0.55 percent.[3] In the absence of any air pollution controls, industry-wide particulate emissions from process sources alone could have exceeded 4.4 Tg (4.9 million tons) in 1975. These emissions, coupled with emissions from fugitive dust sources and the fact that the industry is so widespread (5,400 quarries in 49 States), indicate the need for controls.

1.2 SOURCES AND CONTROL OF EMISSIONS

All quarrying and stone processing operations, including surface mining, crushing, screening, and material handling and transfer operations, are potential sources of particulate emissions. Emission sources may be categorized as either process sources or fugitive dust sources. Process sources include those sources for which emissions are amenable to capture and subsequent control. Fugitive dust sources generally involve the reentrainment of settled dust by wind or machine movement. Factors affecting emissions from either source category include the type, quantity, and the moisture content of the rock processed; the type of equipment and operating practices employed; and topographical and climatic factors.

Principal quarrying operations include drilling, blasting, secondary breakage, and the loading and hauling of broken rock to the stone processing plant. Emissions from drilling operations are caused by the removal of cuttings and dust from the bottom of the hole by air flushing. Generally, two control techniques are available, (1) water injection and (2) the aspiration of dry cuttings to a control device. Although largely uncontrollable, emissions from blasting can be minimized by using good blasting practices and scheduling blasts only under favorable meteorological conditions. If secondary breakage is required, drop-ball cranes are generally used; emissions are relatively small. Emissions generated by the loading of broken rock into in-plant haulage vehicles by front-end loaders or shovels can be controlled by wetting down rock piles prior to loading. At most quarries, large haulage vehicles are used to transport broken rock from the quarry to the stone processing plant over unpaved roads. Emissions generated are proportional to the surface condition of the roads and the volume and speed of the vehicle traffic. Control measures include methods to improve road surfaces including watering, surface treatment with chemical dust suppressants, soil stabilization and paving, and operational changes to reduce traffic volume and vehicle speed.

The principal crushing plant process facilities include crushers, screens, and material handling and transfer equipment. Particulate emissions from process equipment are generally discharged at feed and process material discharge points, and emissions from material handling equipment at transfer points. Available emission control techniques for these plant-generated emissions include wet dust suppression, dry collection, and the combination of the two. Wet dust suppression consists of introducing moisture into the material flow to prevent or suppress the emission of fine particulates. Dry collection involves hooding and enclosing dust-producing points and venting emissions to a collection device. Combination systems utilize both methods at different stages throughout the stone processing plant.

Other particulate emission sources include windblown dust from open conveyors, stockpiles, and the plant yard. Control measures range from the use of dust suppression techniques to the erection of enclosures or windbreaks.

REFERENCES FOR CHAPTER 1

1. Minerals Yearbook 1975 - Volume I: Metals, Minerals, and Fuels, United States Bureau of Mines. 1977. p. 1311.

2. Priorities and Procedures for the Development of Standards of Performance for New Stationary Sources of Atmospheric Emissions, prepared for the United States Environmental Protection Agency by Argonne National Laboratory, Contract Number IAG-0463, Project Number 2. p. 39.

3. Compilation of Air Pollutant Emission Factors, Second Edition, United States Environmental Protection Agency, Publication Number AP-42. April 1973. p. 8.20-1.

2.0 SOURCES AND TYPES OF EMISSIONS

The conversion of naturally occurring mineral deposits into crushed-and broken-stone products involves a series of distinct, yet interdependent, physical operations. These include both quarrying operations such as drilling and blasting, and plant processing operations such as crushing and screening. All these operations are potential sources of significant particulate emissions.

2.1 STONE-PROCESSING OPERATIONS AND THEIR EMISSIONS (GENERAL)

2.1.1 Process Description

The removal of overburden by earth-moving equipment results in a large denuded area that is worked in benches to form an open quarry. Rotary or percussion drills are used to bore blastholes into the exposed stone face. After these blastholes are charged with explosives, the rock is blasted out of its deposit. Insufficient fragmentation may result in the need for secondary breakage. In such cases, "drop-ball" cranes are customarily used. The broken rock is usually loaded into large trucks [18.2- to 68.1-Mg (20- to 75-ton capacity)] by loaders or shovelers and hauled over unpaved roads to the primary crusher, which is often located in or near the quarry pit. In portable plants, usually located in the quarry, material is fed directly to the primary crusher. The broken rock is then transported from the quarry to the plant area.

Plant operations common to most stone-processing installations include primary crushing, scalping, secondary crushing, tertiary or finishing crushing, final screening, conveying, storage and shipping, and in some instances, washing. Depending on the purpose of the plant and the rock type processed, all or only a few of these operations are performed.

As illustrated in Figure 2-1, broken rock obtained from the quarry is dumped into a hoppered feeder, usually a vibrating grizzly type, and fed to the primary crusher for initial reduction. Jaw or gyratory crushers are often used, but impact crushers are gaining favor when low-abrasion rock types (like limestones) are crushed and when high reduction ratios are desired. The crusher product [approximately 76.2 to 305 mm (3 to 12 in.) in size] and the grizzly throughs are discharged onto a belt conveyor and transported to a surge pile or silo for temporary storage.

The material is then reclaimed by a series of vibrating feeders under the surge pile and conveyed to a scalping screen that separates the process flow into three fractions

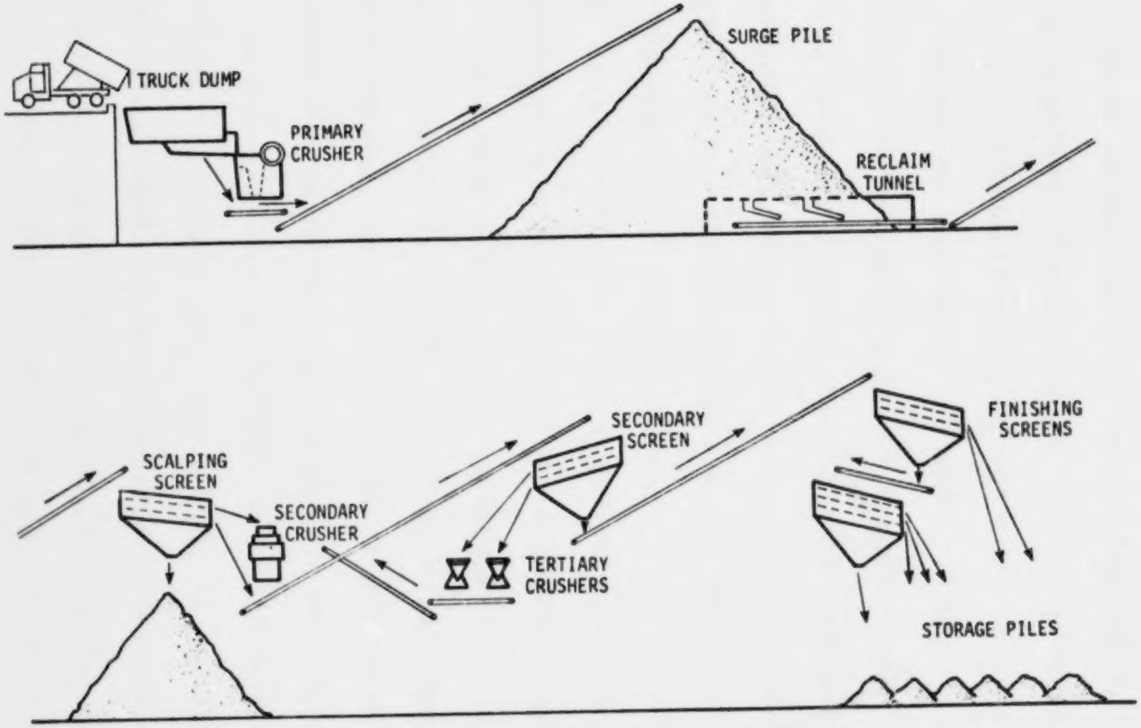

TRUCK DUMP
PRIMARY CRUSHER
SURGE PILE
RECLAIM TUNNEL
SCALPING SCREEN
SECONDARY CRUSHER
SECONDARY SCREEN
TERTIARY CRUSHERS
FINISHING SCREENS
STORAGE PILES

Figure 2-1. Flowsheet of typical crushed-stone plant.

(oversize, undersize, and throughs) prior to secondary crushing. The oversize is discharged to the secondary crusher for further reduction. The undersize, which requires no further reduction at this stage, bypasses the secondary crushers, thus reducing its crushing load. The throughs, which contain unwanted fines and screenings, are removed from the process flow and stockpiled as crusher-run material. Secondary crushers are usually gyratory or cone type, but impact crushers are used at some installations.

The product from the secondary crushing stage, approximately 25.4 mm (1 in.) or less in size, is transported to a secondary screen for further sizing. Sized material from this screen is conveyed or discharged directly to tertiary cone crushers or hammermills. The product from the tertiary crushers is shuttled back to the secondary screen, forming a closed circuit with a fixed-top size. The throughs from this screen are then discharged to a conveyor and elevated to a screen house or tower containing multiple screen lines for final sizing. At this point, end products of desired gradation are discharged directly to finished-product bins or are stockpiled in open areas by conveyors or trucks.

Stone washing is sometimes required to meet particular end-product specifications or demands, such as for concrete aggregate. In washing plants, the material falls onto fine mesh screens, where it is sprayed heavily with water. Unwanted fines are usually discharged to a settling pond.

2.1.2 Sources of Emissions

Unlike emissions from sources such as boilers and incinerators, emissions from sources in this industry have not traditionally been confined and discharged through stacks or similar outlets. Although difficult to do so, emissions from drilling, crushing, screening, and conveyor transfer points can be captured with a hood and vented to a control device. On the other hand, emissions from sources such as blasting, stockpiles, and haul roads cannot be captured by a hood or similar device. Emissions from these sources can, however, often be reduced by wetting the surface, paving haul roads, or implementing a similar measure. Although huge storage silos or enclosures can be constructed to store materials, such a measure is not considered economically feasible for this industry. In assessing a situation like this or when reliable data are not available, engineering judgment has been relied upon to prepare this document.

In this document, sources that are amenable to control by the capture of emissions with a hood or similar device are termed "process" sources while those that are not amenable to this treatment are termed "fugitive dust" sources.

Sources included within each category are listed in Table 2-1. The term stone-processing operations refers to both quarrying and plant operations.

Table 2-1. STONE-PROCESSING EMISSION SOURCES

Process sources	Fugitive dust sources
Drilling	Blasting
Crushing	Loading and hauling
Screening	Haul roads
Conveyor transfer points	Stockpiles
	Conveying

2.1.3 Emissions and Factors that Influence Emissions

All stone-processing operations are potential sources of particulate emissions. Factors affecting emissions that are common to most stone-processing operations include moisture content of the rock, type of rock processed, type of equipment, and operating practices employed. These factors apply to both fugitive dust and process sources in quarry and plant operations.

Depending on geographic and climatic conditions, the inherent moisture content or wetness of quarried rock may range from nearly zero to several percent. The effect of moisture content is especially important during quarrying, material handling, and initial plant process operations such as primary crushing. Surface wetness causes fine particles to agglomerate or adhere to the faces of larger stones, resulting in a dust suppression effect. However, as new fine particles are created by crushing and attrition and moisture content is reduced by evaporation, this suppressive effect diminishes and may even become insignificant.

The type of rock processed is also important. Soft rocks produce a higher percentage of screenings [minus 6.4-mm (1/4-in.) to 200-mesh] than do hard rocks because they are more friable. Therefore, processing of soft rocks has the greater potential for emissions. Major rock types arranged in order of increasing hardness are limestone and dolomite, sandstone, granite, trap rock, quartzite, and quartz.[1] Limestones could therefore be expected to produce the highest uncontrolled emissions, quartzitic materials the least.

The type of equipment and operating practices employed also affect uncontrolled emissions. Equipment selection is based on a variety of parameters, including quarry characteristics, rock type processed, and desired end products. Emissions from process equipment such as crushers, screens, and conveyors are generally a function of the size distribution of the material, and the amount of mechanically induced velocity imparted to it. The effect of equipment type on uncontrolled emissions from all sources is more fully discussed in subsequent sections of this report.

Information is limited on the amount of emissions from crushed-stone operations. Table 2-2 presents emission factors for uncontrolled emissions listed in Compilation of Air Pollutant Emission Factors, AP-42.[2] Based on these estimates, process sources alone, excluding drilling, emit about 5.5 kg of dust per megagram of crushed stone produced (11 lb/ton).

2.2 QUARRYING

Principal quarrying operations include drilling, blasting, secondary breakage, loading, and hauling the broken rock to the plant site. All these operations can cause visible particulate emissions.

Drilling is the boring of holes into bedded rock. These blastholes are charged with explosives and the rock is blasted out of its deposit. Tractor- or truck-mounted pneumatic rotary or percussion drills are commonly used to cut blastholes. Rotary drills cut the blasthole by the abrasive action of a revolving drill bit, usually a roller cone type, which is attached to the end of a drill rod. Percussion drills use compressed air to drive a piston that transmits a series of impacts or hammerblows either through the drill rod or directly to the bit. This type of drill

Table 2-2. PARTICULATE EMISSION FACTORS FOR STONE-PROCESSING OPERATIONS[2]

Process operation	Uncontrolled emission factor[a]	
	kg/Mg	(lb/ton)
Primary crushing	0.25	(0.5)
Secondary crushing and screening	0.75	(1.5)
Tertiary crushing and screening	3.0	(6.0)
Recrushing and screening	2.5[b]	(5.0[b])
Screening, conveying, and handling	1.0	(2.0)
	5.5	(11.0)

[a] Based on primary crusher throughput.

[b] Based on recrushing and screening throughput. Assuming 20 percent of the primary crusher throughput undergoes recrushing, the emission factor may be expressed as 0.5 kg/Mg of primary crusher throughput (1 lb/ton).

forms the blasthole by the chipping and pulverizing action of the bit impacting against the rock surface. Rotary drills are normally used in softer rock formations like limestones, and percussion drills are used for harder rocks. The number, depth, spacing, and diameter of blastholes depend on the characteristics of the explosive used, the type of burden or rock to be fragmented, and characteristics of the rock formation, such as the location of dips, joints, and seams.

Emissions from drilling operations are caused primarily by the removal of cuttings and dust from the bottom of the hole. Compressed air released down the hollow drill center forces cuttings and dust up and out the annular space formed between the hole wall and drill. The type of rock drilled, its moisture content, the type of drill used, the hole diameter, and penetration rate all affect the amount of uncontrolled emissions. An estimate for granite is 0.4 g/Mg (0.0008 lb/ton) stone.[3]

Blasting is used to displace solid rock from its quarry deposit and fragment it into sizes that will require a minimum of secondary breakage and can be readily handled by loading and hauling equipment. Blastholes are loaded with a predetermined amount of explosives, which are then stemmed and detonated. Explosives most commonly used in the industry are dynamites and blasting agents. Dynamites are highly explosive and come in a variety of types and grades, many of which contain nitroglycerine. Blasting agents are insensitive chemical mixtures of fuels and oxidizers. Mixtures of ammonium nitrate and fuel oil (ANFO) are the most common types of blasting agents and consist of coated or uncoated fertilizer-grade ammonium nitrate pellets, prills, or granules mixed with 4 to 6 percent fuel oil.

Blasting frequency ranges from several shots per day to one per week, depending on the plant capacity and the size of individual shots. The effectiveness of a shot depends on the characteristics of the explosive and the rock. Emissions from blasting are obvious as detected by visual observation and inherently unavoidable. Factors affecting emissions include the size of the shot, blasting practices employed, rock type, and wetness. An estimate for granite is 80 g/Mg (0.16 lb/ton) of stone.[3]

Secondary breakage, if required, is usually done by drop-ball cranes. Normally, a pear-shaped or spherical drop-ball, weighing several tons, is suspended by a crane and dropped on the oversize rock as many times as needed to break it. Emissions are relatively insignificant as judged by visual observations.

Broken rock is normally excavated and loaded onto trucks by shovelers and front-end loaders. The broken rock is either dumped directly into the primary crusher (when portable plants are used) or into large 18.2- to 68-Mg (20- to 75-ton) trucks for transport to the primary crusher, located at the plant or near the quarry site.

At most quarries, the broken rock is transported from the quarry to the primary crusher over unpaved haul roads. Traffic on these roads is responsible for a large portion of the fugitive dust generated by quarrying operations. The amount of fugitive dust ranges from 1.68 to 4.45 kg (3.7 to 9.8 lb) per vehicle mile on a "dry" day.[3] Assuming 166 dry days, this translates to yearly range of 0.48 to 1.23 kg (1.7 to 4.5 lb) per vehicle km (mile) per year.[3] Factors affecting fugitive dust emissions from hauling operations include the composition of the road surface, the wetness of the road, and the volume and speed of the vehicle traffic.

2.3 CRUSHING

Crushing or comminution is the process by which coarse material is reduced to a desired size for mechanical separation (screening) by application of mechanical energy and by attrition. During crushing, sufficient mechanical stress is applied to a rock particle to fracture it. The mechanical stress is applied by either compression or impact. With impact stress, the breaking force is applied almost instantaneously, whereas with compression, the rock particle is squeezed relatively slowly until it fractures. All crushers use both compression and impaction. Table 2-3 ranks crushers according to the predominant crushing mechanism used (from top to bottom, compression to impaction). In all cases, some reduction is accomplished by attrition, the rubbing of stone on stone or on metal surfaces.

The size of the product from compression-type crushers is controlled by the crusher setting at the bottom of the crushing chamber (the space between the crushing surfaces compressing the stone particle). This produces a relatively closely graded product with a small proportion of fines. In contrast, crushers that reduce by impact produce a wide range of sizes and a high proportion of fines.

Because the size reduction achievable by one machine is limited, two or more reduction stages are required. As noted previously, the various stages include primary, secondary, and tertiary crushing. Basically, four types of crushers are used in the industry: jaw, gyratory, roll, and impact crushers.

Table 2-3. MAJOR CRUSHING MECHANISM UTILIZED BY VARIOUS CRUSHERS

Compression	Double-roll crusher
	Jaw crusher
	Gyratory crusher
	Single-roll crusher
	Rod mill (low speed)
	Ball mill
	Rod mill (high-speed)
	Hammermill (low-speed)
	Impact breaker
Impaction	Hammermill (high-speed)

2.3.1 Types of Crushing Equipment

Jaw Crushers --

Jaw crushers consist of a vertical fixed jaw and a moving inclined jaw that is operated by single or paired toggles. Rock is crushed by compression as a result of the opening and closing action of the movable jaw against the fixed jaw. Jaw crushers are principally used in the industry for primary crushing.

The most commonly used jaw crusher is the Blake or double-toggle type. As illustrated in Figure 2-2, an eccentric shaft drives a Pitman arm that raises and lowers a pair of toggle plates to open and close the moving jaw which is suspended from a fixed shaft. In a single-toggle jaw crusher, the moving jaw itself is suspended from an eccentric shaft. The lower part of the jaw is supported by a rolling toggle plate (Figure 2-3). Rotation of the eccentric shaft produces a circular motion at the upper end of the jaw and an elliptical motion at the lower end.

The size of a jaw crusher is defined by its feed opening dimensions, which may range from about 152 by 304 mm (6 by 12 in.) to 2.13 by 1.68 mm (84 by 66 in.). The size reduction obtainable may range from 3:1 to 10:1, depending on the nature of the rock. Crusher capacities are variable and depend on the unit and its discharge setting. Table 2-4

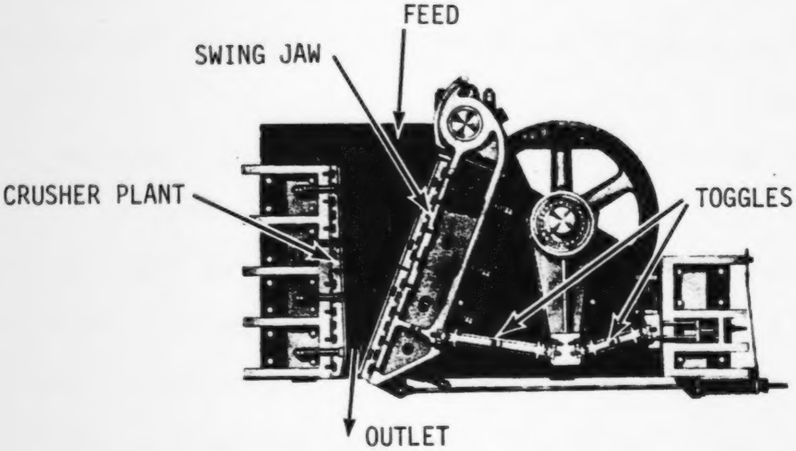

FEED
SWING JAW
CRUSHER PLANT
TOGGLES
OUTLET

Figure 2-2. Double-toggle jaw crusher (Courtesy of Pit and Quarry Handbook).

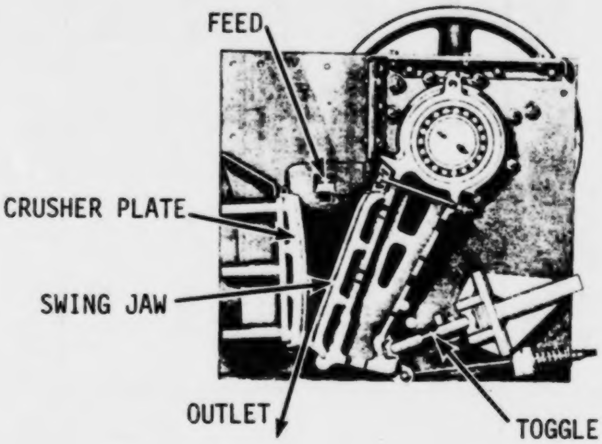

FEED
CRUSHER PLATE
SWING JAW
OUTLET
TOGGLE

Figure 2-3. Single-toggle jaw crusher (Courtesy of Pit and Quarry Handbook).

Table 2-4. APPROXIMATE CAPACITIES OF JAW CRUSHERS[4]

(Discharge opening - closed)

Size mm (in.)	Smallest discharge opening, mm (in.)	Capacity[a] Mg/h (tons/h)	Largest discharge opening, mm (in.)	Capacity Mg/h (tons/h)
0.914 x 0.610 (36 x 24)	76 (3)	68.0 (75)	152 (6)	145.1 (160)
1.07 x 1.52 (42 x 60)	101 (4)	118.1 (130)	203 (8)	181.4 (200)
1.22 x 1.07 (48 x 42)	127 (5)	158.8 (175)	203 (8)	249.5 (275)
1.52 x 1.22 (60 x 48)	127 (5)	217.8 (240)	229 (9)	408.2 (450)
2.13 x 1.68 (84 x 66)	203 (8)	362.9 (400)	305 (12)	544.3 (600)

[a] Based on rock weighing 1.604 Mg/m^3 (100 lb/ft^3).

presents approximate capacities for a number of jaw-crusher sizes at both minimum and maximum discharge settings.

Gyratory Crushers --

A gyratory crusher is a jaw crusher with circular jaws that crush the material between it. As indicated in Table 2-5, a gyratory crusher has a much greater capacity than a jaw crusher with an equivalent feed opening.

The three basic types of gyratory crushers are pivoted-spindle, fixed-spindle, and cone. The fixed- and pivoted-spindle gyratory crushers are used for primary and secondary crushing, and cone gyratory crushers for secondary and tertiary crushing. The large gyratory crushers are sized according to feed opening, and the small units according to cone diameter.

The pivoted-spindle gyratory crusher (Figure 2-4) is a crushing head mounted on a shaft that is suspended from above and is free to pivot. The bottom of the shaft is seated in an eccentric sleeve that revolves, thus causing the crusher head to gyrate in a circular path within a stationary concave circular chamber. The crushing action is similar to that of a jaw crusher in that the crusher element reciprocates to and from a fixed crushing plate. Because part of the crusher head is working at all times, the discharge from the gyratory crusher is continuous rather than

Table 2-5. APPROXIMATE CAPACITIES OF GYRATORY CRUSHERS[4]

Size mm (in.)	Smallest discharge opening, mm (in.)	Capacity[a] Mg/h (tons/h)	Largest discharge opening, mm (in.)	Capacity Mg/h (tons/h)
0.762 (30)	101 (4)	181.4 (200)	165 (6-1/2)	408.2 (450)
0.914 (36)	114 (4-1/2)	335.5 (370)	178 (7)	544.3 (600)
1.067 (42)	101 (4)	380.9 (420)	191 (7-1/2)	635.0 (700)
1.219 (48)	140 (5-1/2)	680.4 (750)	229 (9)	1088.0 (1200)
1.372 (54)	159 (6-1/4)	816.5 (900)	241 (9-1/2)	1451.5 (1600)
1.524 (60)	178 (7)	1088.0 (1200)	254 (10)	1814.0 (2000)
1.829 (72)	229 (9)	1814.0 (2000)	305 (12)	2721.6 (3000)

[a] Based on rock weighing 1.604 Mg/m^3 (100 lb/ft^3).

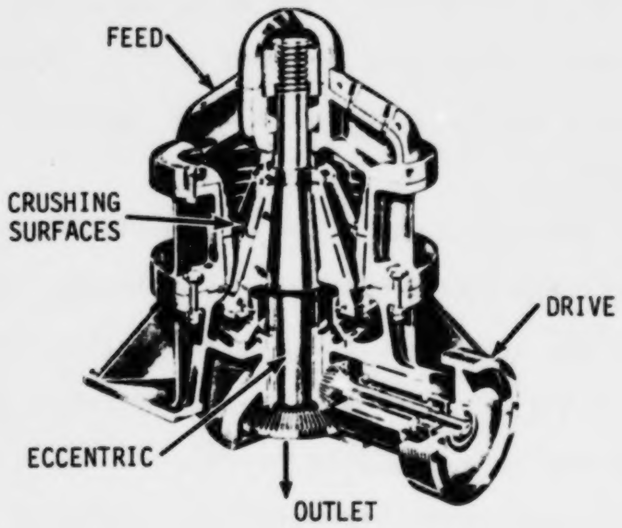

FEED
CRUSHING SURFACES
DRIVE
ECCENTRIC
OUTLET

Figure 2-4. Gyratory crusher
(Courtesy of Pit and Quarry Handbook).

intermittent as in a jaw crusher. The crusher setting is determined by the wide-side opening at the discharge end and is adjusted by raising or lowering the crusher head.

Unlike the pivoted-spindle gyratory crusher, the fixed-spindle gyratory crusher has a crushing head mounted on an eccentric sleeve fitted over a fixed shaft. This produces a uniform crushing stroke from the top to the bottom of the crushing chamber.

For fine crushing, the gyratory crusher is equipped with flat heads and converted to a cone crusher (Figure 2-5). Usually, the lower section has a parallel zone. This results in a large discharge-to-feed area ratio that makes it especially suitable for fine crushing at high capacity. Also, unlike regular gyratory crushers, the cone crusher sizes at the closed-side setting and not the open-side setting. This assures that the material discharge is crushed at least once at the closed-side setting. Cone crushers yield a cubical product and a high percentage of fines because of interparticle crushing (attrition). They are the most commonly used crusher in the industry for secondary and tertiary reduction. Table 2-6 presents performance data for typical cone crushers.

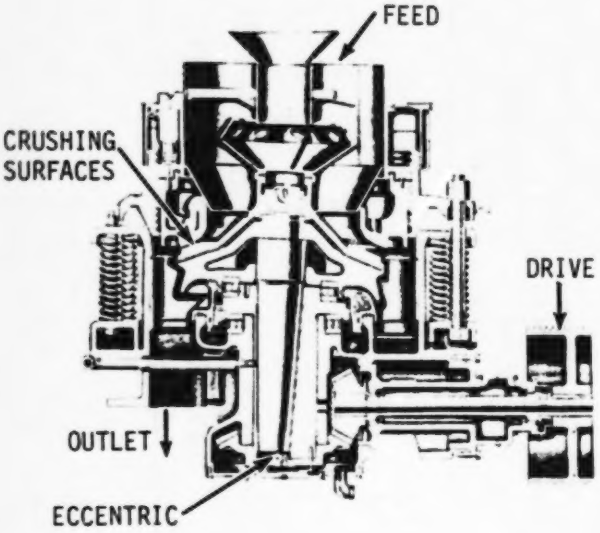

FEED
CRUSHING SURFACES
DRIVE
OUTLET
ECCENTRIC

Figure 2-5. Cone crusher
(Courtesy of Pit and Quarry Handbook).

Table 2-6. CAPACITIES OF CONE CRUSHERS[5]

[Mg/h (tons/h) except as noted]

Size of crusher, m (ft)	Discharge setting				
	9.5 mm (3/8 in.)	12.7 mm (1/2 in.)	19.1 mm (3/4 in.)	25.4 mm (1 in.)	28.1 mm (1-1/2 in.)
0.61 (2)	18.0 (20)	22.7 (25)	31.7 (35)		
0.91 (3)	31.7 (35)	36.0 (40)	64.8 (70)		
1.22 (4)	54.0 (60)	72.0 (80)	108.0 (120)	137.0 (150)	
1.68 (5-1/2)			180.0 (200)	248.0 (275)	310.0 (340)
2.13 (7)			299.0 (300)	407.0 (450)	544.0 (600)

Roll Crushers --

Single-roll and double-roll crushers are used primarily at intermediate or final reduction stages and often at portable plants. As illustrated in Figure 2-6, the double-roll crusher consists of two heavy parallel rolls that turn toward each other at identical speeds ranging from 50 to 300 revolutions per minute. Usually, one roll is fixed and the other set by springs. Roll diameters normally range from 0.6 to 2.0 m (24 to 78 in.) with narrow face widths about half the roll diameter. Rock particles are caught between the rolls and crushed almost totally by compression at a reduction ratio of 3 or 4 to 1. These units, which produce few fines and no oversize, are especially effective for reducing hard stone to a final product ranging from 6.4 m (1/4 in.) to 20-mesh.

The working elements of a single-roll crusher include a toothed or knobbed roll and a curved crushing plate, which may be corrugated or smooth. The crushing plate is generally hinged at the top, and its setting is held by a spring at the bottom, as shown in Figure 2-7. The feed, caught between the roll and crushing plate, is broken by a combination of compression, impact, and shear. These units accept feed sizes up to 0.51 m (20 in.) and have capacities up to 454 Mg/h (500 tons/h). In contrast with the double-roll,

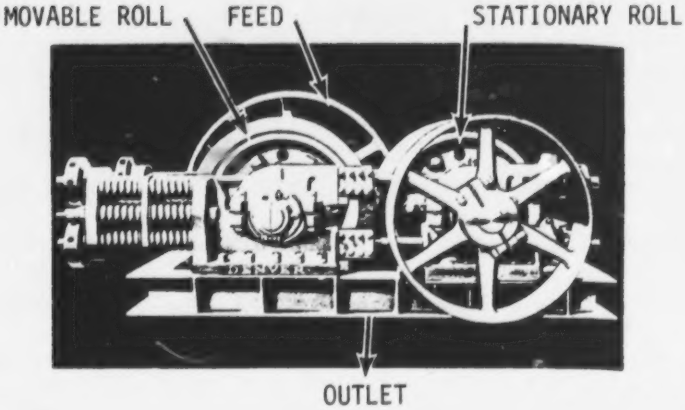

MOVABLE ROLL
FEED
STATIONARY ROLL
OUTLET

Figure 2-6. Double-roll crusher (Courtesy of Pit and Quarry Handbook).

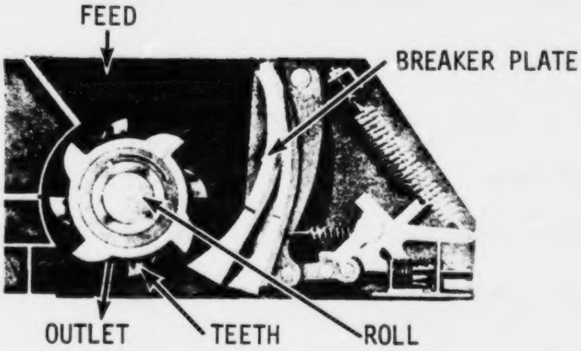

FEED
BREAKER PLATE
OUTLET
TEETH
ROLL

Figure 2-7. Single-roll crusher (Courtesy of Pit and Quarry Handbook).

the single-roll crusher is used principally for reducing soft materials such as limestones.

Impact Crushers --

Impact crushers, including hammermills and impactors, use the force of fast-rotating, massive impellers or hammers to shatter free-falling rock particles. These units have very high reduction ratios and produce a cubical product spread over a wide range of particle sizes with a large proportion of fines. This makes their application in industries such as cement manufacturing and agstone production extremely cost effective by reducing the need for subsequent grinding machines.

A hammermill consists of a high-speed horizontal rotor having several rotor discs to which sets of hammers are attached (Figure 2-8). As rock particles are fed into the crushing chamber, they are shattered by the hammers, which attain peripheral speeds as high as 76.2 m/s (250 ft/s). The shattered rock then collides with a steel breaker plate and is fragmented even further. A cylindrical grating or screen positioned at the discharge opening restrains oversize material until it is reduced to a size small enough to pass between the grate bars. Rotor speeds range from 250 to 1800 revolutions per minute, and capacities to over 907 Mg/h (1000 tons/h). Product size is controlled by rotor speed, spacing between the grate bars, and hammer length.

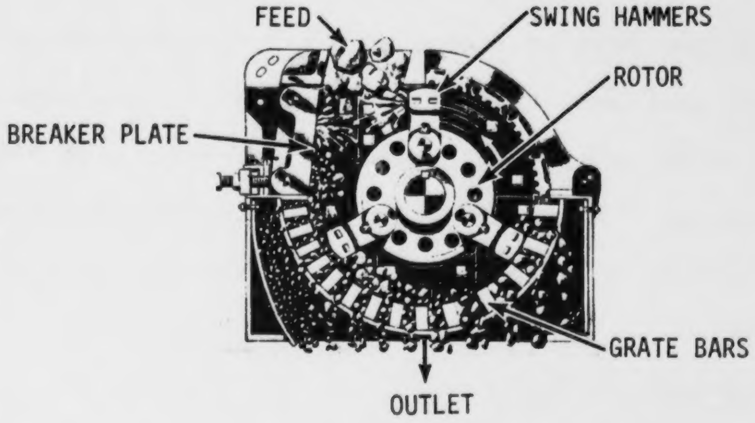

FEED
SWING HAMMERS
ROTOR
BREAKER PLATE
GRATE BARS
OUTLET

Figure 2-8. Hammermill crusher
(Courtesy of Pit and Quarry Handbook).

An impact breaker (Figure 2-9) is similar to a hammermill except that it has no grate or screen to act as a restraining member. Feed is broken by impact alone. Adjustable breaker bars are used instead of plates to reflect material back into the path of the impellers. Primary-reduction units are available that can reduce quarry-run material to about 25.4 mm (1 in.) at a capacity of more than 907 Mg/h (1000 tons/h). Although these units are not appropriate for hard, abrasive materials, they are ideal for soft rock such as limestone.

2.3.2 Sources of Emissions

The generation of particulate emissions is inherent in the crushing process. Emissions are most apparent at crusher feed and discharge points. Emissions may be influenced by a variety of factors, including moisture content of the rock, type of rock processed, and type of crusher used. All but the last have been previously discussed.

Whether the crushing equipment is compression or impact type has the greatest influence on emissions. The mechanism affects particle size distribution of the product, especially the proportion of fines produced, and the amount of mechanically induced energy that is imparted to these fines.

Impact crushers produce a larger proportion of fines than do compression crushers. This is illustrated in

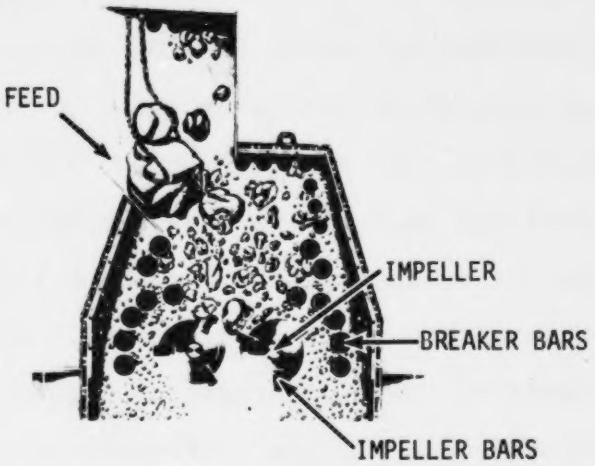
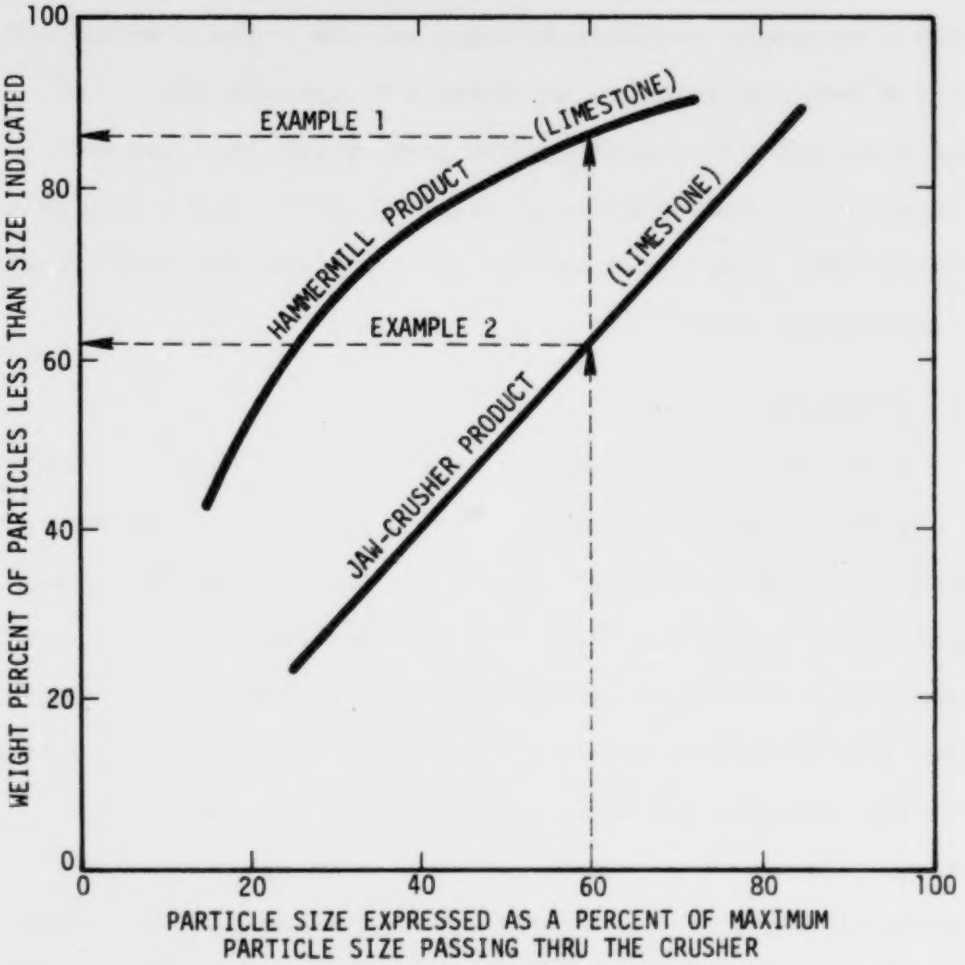

FEED
IMPELLER
BREAKER BARS
IMPELLER BARS

Figure 2-9. Impact crusher
(Courtesy of Pit and Quarry Handbook).

Figure 2-10, which compares the particle size distributions produced by the reduction of limestone with a hammermill and a jaw crusher. The distribution curve for the hammermill is characteristic of impact crushers in general and demonstrates the high proportion of fines contained in the crusher product. The distribution curve for the jaw crusher illustrates the particle size distribution produced by compression-type crushers including jaw, gyratory, cone, and roll crushers. These crushers are designed to reduce material to a size regulated by the crusher setting, the gap between the crushing faces at the point of discharge. The slope of the curve demonstrates how a compression crusher produces a large proportion of particles corresponding to the crusher setting.

In addition to generating more fines, impact crushers also impart more velocity to them as a result of the fan-like action produced by the whirling hammers. For these two reasons, impact crushers generate more uncontrolled particulate emissions per Mg (ton) of stone processed than any other crusher type.

The uncontrolled emissions from jaw, gyratory, cone, and roll crushers closely parallel the reduction stage to which they are applied. As indicated in Table 2-2, the greater the reduction, the higher the emissions. In all



EXAMPLE 1 - HAMMERMILL PRODUCT HAVING A MAXIMUM SIZE OF 38.1 mm (1.5 IN.), APPROXIMATELY 85% (BY WEIGHT) OF THE PRODUCT WOULD BE LESS THAN 22.9 mm (0.9 IN). (60% X 1.5).

EXAMPLE 2 - JAW-CRUSHER PRODUCT HAVING A MAXIMUM SIZE OF 101.6 mm (4 IN.), APPROXIMATELY 62% (BY WEIGHT) OF THE PRODUCT WOULD BE LESS THAN 61.0 (2.4 IN.) (60% X4).

Figure 2-10. Characteristic Particle Size Distribution for Different Crushing Mechanisms.[6]

likelihood, primary jaw crushers produce more dust than comparable gyratory crushers because of the bellows effect of jaw and because gyratory crushers are usually choke-fed, thus minimizing the open spaces from which dust may be emitted. For subsequent reduction stages, cone crushers produce more fines as a result of attrition and consequently generate more dust.

2.4 SCREENING

Screening is the process by which a mixture of stones is classified and separated according to size. The material to be screened is dropped onto a screening surface with openings of a desired size. It is then separated into two fractions, undersizes which pass through the screen openings, and oversizes which are retained on the screen surface. Multiple screens are used to divide the material into several fractions of known particle size distribution. Screening surfaces may be constructed of metal bars, perforated or slotted metal plates, or woven wire cloth. Woven screens may range in mesh size from 101.6 mm (4 in.) to 400-mesh [0.841 mm (0.0331 in.)].

The efficiency of a screening operation is a measure of its success in separating two or more material fractions. Screening efficiency in the crushed-stone industry ranges from 60 to 75 percent. The capacity of a screen, determined primarily by the open area of the screening surface and the physical characteristics of the feed, is usually expressed in Mg/h per m^2 (tons/h per ft^2). Although screening may be performed wet or dry, dry screening is the more common.

Screening equipment commonly used in the crushed-stone industry includes grizzlies, shaking screens, vibrating screens, and revolving screens.

2.4.1 Types of Screening Equipment

Grizzlies --

Grizzlies consist of a set of uniformly spaced horizontal or inclined bars, rods, or rails. The bars are usually wider on the top surface than they are on the underside to prevent stone particles from becoming wedged between them. The spacing between the bars ranges from 60.8 to 203.2 mm (2 to 8 in.). Bars are usually constructed of manganese steel or other highly abrasion-resistant material.

Grizzlies are used mainly to remove fines prior to primary crushing, thus reducing the load on the primary crusher. Grizzlies may be stationary, cantilevered (fixed at one end with the discharge end free to vibrate), or mechanically vibrated. Vibrating grizzlies are simple bar grizzlies mounted on eccentrics (Figure 2-11). The entire assembly oscillates at about 100 strokes a minute to promote better flow through and across the grizzly surface.

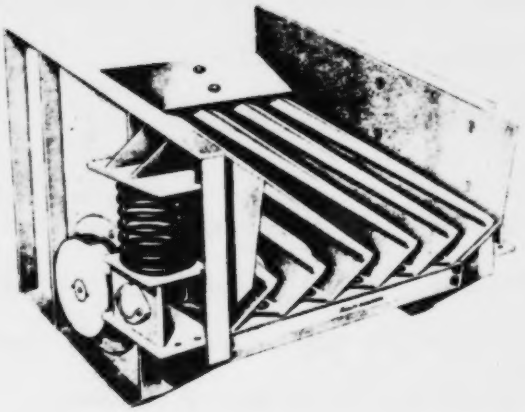


Figure 2-11. Vibrating grizzly
(Courtesy of Pit and Quarry Handbook).

Shaking screens --

The shaking screen consists of a retangular frame with perforated plate or wire cloth screening surfaces. These screens, usually suspended by rods or cables and inclined at an angle of 14 degrees, are mechanically shaken parallel to the plane of material flow at speeds ranging from 60 to 800 strokes per minute and at amplitudes ranging from 19.5 to 228.6 mm (3/4 to 9 in.). They are used for screening coarse material 12.7 mm (1/2 in.) or larger.

Vibrating screen --

The vibrating screen has replaced most other screen types when a large capacity and high efficiency are desired. It is by far the most commonly used screen type in the crushed-stone industry. A vibrating screen (Figure 2-12) essentially consists of an inclined flat or slightly convex screening surface that is rapidly vibrated in a plane normal or nearly normal to the screen surface. The screening motion is of small amplitude but high frequency, normally in excess of 3000 cycles per minute. The vibrations may be generated either mechanically by means of an eccentric shaft, unbalanced fly wheel, cam, and tappet assembly, or electrically by means of an electromagnet.

Mechanically vibrated units are operated at about 1200 to 1800 rpm and at amplitudes of about 3.1 to 12.7 mm (1/8

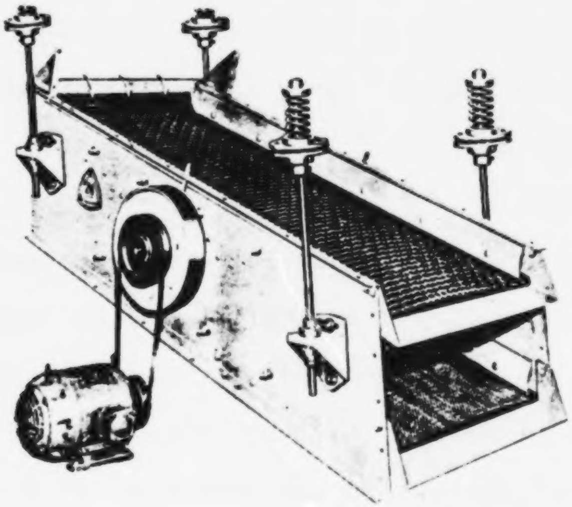


Figure 2-12. Vibrating screen (Courtesy of Pit and Quarry Handbook).

to 1/2 in.). Electrically vibrated screens are available in standard sizes from 0.3 to 1.8 m (12 in. to 6 ft) wide and 0.8 to 6.1 m (2-1/2 to 20 ft) long. A complete screening unit may have one, two, or three decks.

Revolving screens --

This screen type consists of an inclined cylindrical frame around which is wrapped a screening surface of wire cloth or perforated plates. Feed material is delivered at the upper end and, as the screen is rotated, undersized material passes through the screen openings while the oversized is discharged at the lower end. Revolving screens are available up to 1.2 m (4 ft) in diameter and usually run at 15 to 20 revolutions per minute.[4]

2.4.2 Source of Emissions

Dust is emitted from screening operations as a result of the agitation of dry stone. The level of uncontrolled emissions depends on the particle size of the material screened, the amount of mechanically induced energy transmitted, and other factors previously discussed.

Generally, the screening of fines [less than 3.2 mm (1/8 in.)] produces higher emissions than the screening of coarse sizes. Also, screens agitated at large amplitudes and high frequency emit more dust than those operated at small amplitudes and low frequencies.

2.5 MATERIAL HANDLING

Throughout a crushed-stone plant handling devices are used to transport materials from one point to another. The most common devices include feeders, belt conveyors, bucket elevators, and screw conveyors. Pneumatic systems are rarely used in this industry.

2.5.1 Types of Handling Equipment

Feeders --

Feeders are relatively short, heavy-duty conveying devices that receive material from and deliver it to process units, especially crushers, at a uniform rate. The various types of feeders used are the apron, belt, reciprocating-plate, vibrating, and wobbler.

Apron feeders are composed of overlapping metal pans or aprons hinged together or linked by chains to form an endless conveyor that is supported by rollers spaced between a head and tail assembly. These units are constructed to withstand high impact and abrasion and are available in various widths [0.46 to 1.8 mm (18 to 72 in.)] and lengths.

Belt feeders are essentially short, heavy-duty conveyor belts equipped with closely spaced support rollers. Adjustable gates are used to regulate feed rates. This type of feeder is available in 0.48- to 1.2-m (18- to 48-in.) widths and 0.91- to 3.7-m (3- to 12-ft) lengths, and is operated at speeds of 0.2 to 0.51 m/s (40 to 100 ft/min).

A reciprocating-plate feeder is a heavy-duty horizontal plate driven in an oscillating motion that causes the material to move forward at a uniform rate. The feed rate is controlled by adjusting the frequency and length of the stroke.

Vibrating feeders operate at a relatively high frequency and low amplitude. Their feed rate is controlled by the slope of the feeder bed and the amplitude of the vibrations. These feeders are available in a variety of sizes, capacities, and drives. When combined with a grizzly, they perform both scalping and feeding functions.

Wobbler feeders also perform the dual task of scalping and feeding. These units consist of a series of closely spaced elliptical bars that are mechanically rotated, causing oversize material to tumble forward to the discharge end and undersize material to pass through the spaces. The feed rate is controlled by the bar spacing and the speed of rotation.

Belt conveyors --

Belt conveyors are the most widely used means of transporting, elevating, and handling materials in the crushed-stone industry. As illustrated in Figure 2-13, a belt conveyor is an endless belt supported on a series of idlers that are usually arranged so that the belt forms a trough.

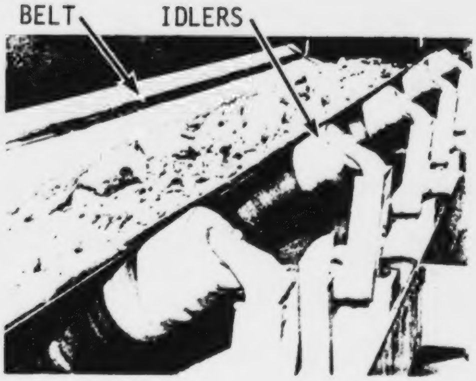

BELT
IDLERS

Figure 2-13. Belt conveyor
(Courtesy of Pit and Quarry Handbook).

The belt, commonly constructed of reinforced rubber, is stretched between a drive or head pulley and a tail pulley. Although belt widths may range from 0.36 to 1.6 m (14 to 60 in.), widths of 0.76 to 0.91 m (30 to 36 in.) are the most common. Normal operating speeds may range from 1.0 to 20 m/s (200 to 400 ft/min). Depending on the rock density, belt width, and belt speed, load capacities may be in excess of 136 Mg/h (1500 tons/h).

Elevators --

Bucket elevators are utilized when substantial elevation is required within a limited space. The buckets are attached to a single- or double-strand chain or belt that is supported and driven by a head and foot assembly. Figure 2-14 depicts the three most common types of bucket elevators, high-speed centrifugal-discharge, slow-speed positive- or perfect-discharge, and continuous-discharge.

In the centrifugal-discharge elevator, the buckets are evenly spaced on a single-strand chain or belt. As the buckets round the tail pulley, which is housed within a suitable curved boot, they scoop up their load and elevate it to the point of discharge. The buckets are spaced so that at discharge the material is thrown out by the centrifugal action of the bucket rounding the head pulley.

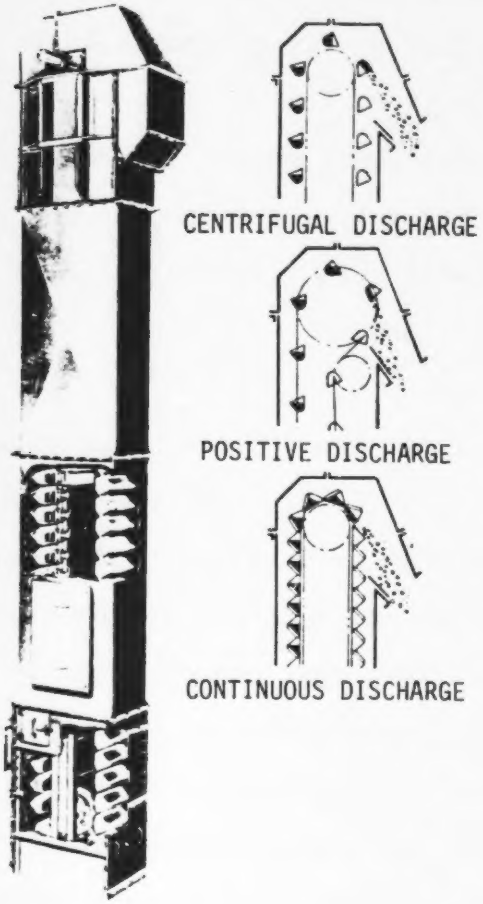

CENTRIFUGAL DISCHARGE
POSITIVE DISCHARGE
CONTINUOUS DISCHARGE

Figure 2-14. Bucket elevators

(Courtesy of Pit and Quarry Handbook).

The positive-discharge elevator also has spaced buckets, but it has a double-strand chain and a different discharge mechanism. An additional sprocket set below the head pulley effectively bends the strands back under the pulley, causing the bucket to be totally inverted and resulting in a positive discharge.

The continuous-discharge elevator utilizes closely spaced buckets attached to a single- or double-strand belt or chain. Material is loaded directly into the buckets during ascent and is discharged gently. The back of the preceding bucket is used as a discharge chute.

Screw conveyors --

Screw conveyors are comprised of a steel shaft with a spiral or helical fin that when rotated pushes material along a trough. Because these conveyors are normally used with wet material, they create no significant emission problem.

2.5.2 Source of Emissions

Particulates may be emitted from any of the material handling (conveying) operations. Most of the emissions from material handling occur at transfer points, since transport of material on the conveyor causes little disturbance of air, and emissions that occur due to the wind are judged to be minimal. The transfer points include transfers from a conveyor onto another, into a hopper, and onto a storage pile. The amount of uncontrolled emissions depends on the size distribution of the material handled, the belt speed, and the free-fall distance. Reference 3 estimates an emission rate of 750 g/Mg (1.5 lb/ton) from transfer and conveying operations in a crushed-granite plant.[3]

2.6 WASHING

To meet specifications some aggregate products such as concrete aggregate require washing to remove fines. Although a variety of equipment is available, washing screens are generally used. A washing screen is a standard, inclined, vibrating screen with high-pressure water-spray bars installed over the screening surface. Stone passing over the screen is washed and classified. Because it is a wet process, it essentially produces no particulate emissions.

2.7 PORTABLE PLANTS[7]

A portable plant may consist of a single chassis on which one or several processing units may be mounted, or it may consist of a combination of chassis on which various types of units are mounted to provide a sequence of operations such as feeding, crushing, screening, sizing, washing, and stacking or loading. The processing steps for crushed stone are the same in both stationary and portable plants.

In a portable plant, however, the processing units are squeezed into a very restricted space. Thus, the entire plant can be readily moved from one quarry site to another.

Portable plants come in various designs and are adaptable to practically any process conditions and product specifications. They may be grouped into three categories: simple, duplex, and combination. In the simple portable plant a single screen receives material from a feed conveyor. The oversized material is scalped to a jaw crusher, where it is reduced before it is returned to the feed conveyor. The material that passes through the scalping screen is the lone product that is collected in a truck or bin directly underneath the screen.

Additional product sizes may be produced by adding a secondary crusher and modifying the screening arrangement. This grouping that is commonly mounted on a single chassis is known as a Duplex plant. As shown in Figure 2-15, pit material is fed to the top of a triple-deck, inclined, vibrating screen capable of producing three product sizes and oversize which is reduced by a jaw crusher. Material that is passed to the second screening deck is delivered to a double- or triple-roll crusher for secondary reduction. The output from both crushers is conveyed to a rotating drum-type elevator that returns the material to the feed

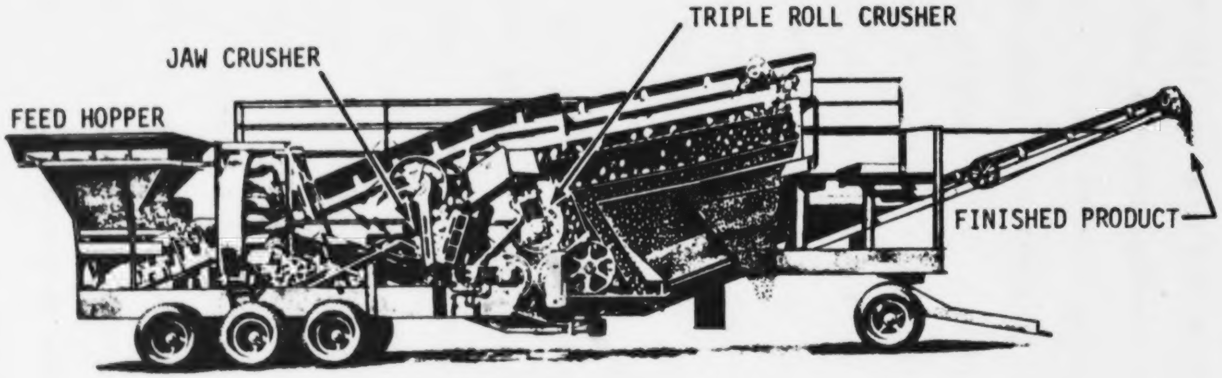

FEED HOPPER
JAW CRUSHER
TRIPLE ROLL CRUSHER
FINISHED PRODUCT

Figure 2-15. Portable Plant

(Courtesy of Pit and Quarry Handbook).

conveyor. Material passing through the second screen to the third is classified by size, collected in bins, and conveyed to storage piles. Combination plants have two or more chassis with various combinations of processing units.

Portable plants may be used as auxiliary units to large stationary primary crushers in quarries that produce pit material too large for the portable plant to handle alone. The ability of some portable plants, however, is too limited to accept the feed from the larger primary crushers. Therefore, a secondary or intermediate crusher, which may also be a portable unit, is required to take full advantage of the capability of the primary crusher.

Conversely, some process conditions preclude the need for an intermediate crusher, and the flexibility of individual portable processing units allows the user to meet his product requirements simply by arranging the units in the most efficient combination.

Emissions from each processing unit in a portable plant are the same as those from a unit of equivalent size in a stationary plant.

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3.0 EMISSION REDUCTION TECHNIQUES

Diverse particulate emission sources in stone-processing operations have resulted in the use of a variety of control methods and techniques. Dust-suppression techniques are the most commonly used. They are designed to prevent particulate matter from becoming airborne and are applicable to both process and fugitive dust sources. Particulate emissions such as those generated by crushing operations can be captured in collection systems. Emission sources and applicable control options are listed in Table 3-1.

3.1 CONTROL OF QUARRYING OPERATIONS[1]

3.1.1 Control of Drilling Operations

Generally, two methods are available for controlling particulate emissions from drilling operations: water injection and aspiration to a control device.

Water injection is a wet-control technique in which water or water plus a wetting agent or surfactant, usually a liquid detergent, is forced into the compressed air stream that flushes the drill cuttings from the hole. The injection of fluid into the airstream produces a mist that dampens the stone particles and causes them to agglomerate. As the

Table 3-1. EMISSION SOURCES AND CONTROL OPTIONS

Operation or source	Control options
Drilling	Liquid injection (water or water plus a wetting agent). Capturing and venting emissions to a control device.
Blasting	No control.
Loading	Water wetting.
Hauling (emissions from roads)	Water wetting. Treatment with surface agents. Soil stabilization. Paving. Traffic control.
Crushing	Wet-dust suppression systems. Capturing and venting emissions to a control device.
Screening	Same as for crushing.
Conveying (transfer points)	Same as for crushing.
Stockpiling	Stone ladders. Stacker conveyors. Water sprays at conveyor discharge.
Conveying	Covering. Wet dust-suppression.
Windblown dust from stockpiles	Water wetting. Surface active agents. Covering. Windbreaks.
Windblown dust from roads	Oiling. Surface active agents. Soil stabilization. Paving. Sweeping.

particles are blown from the hole, most of them drop at the drill collar as damp pellets rather than becoming airborne.

The addition of a wetting agent increases the wetting ability of untreated water by reducing its surface tension.[2] This reduces the amount of water required for effective control, thereby minimizing the drawbacks of decreased penetration rate, increased wear, restricted chip circulation, increased back pressure at the bottom of the hole, and potential collaring (drill sticking in the hole). The amount of solution required is dependent upon the size of the hole, the drilling rate, and the type of material being drilled. A typical injection rate for an 89-mm (3-1/2-inch) diameter hole is about 26.5 liters/h (7 gal/h). The effective application of water injection to a drilling operation should eliminate visible emissions.

Dry collection systems also are used to control emissions from the drilling process. A shroud or hood encircles the drill rod at the hole collar. A vacuum captures emissions and vents them through a flexible duct to a control device for collection. Control devices most commonly used are cyclones or fabric filters preceded by a settling chamber. Cyclone collection efficiencies usually are not high. Although designed well for the collection of coarse- to medium-sized particles (15 to 40 μm or larger), cyclones are generally unsuitable for fine particulates (10 μm and smaller) because their collection efficiencies seldom exceed 80 percent in this size range.[3] Fabric filter collectors, however, exhibit collection efficiencies in excess of 99 percent through the submicron particle range.[3] Air volumes required for effective control may range from 0.235 to 0.705 m^3/s (500 to 1500 ft^3/min) depending on the type of rock drilled, hole size, and penetration rate. A rotary drill equipped with a baghouse was tested for visible emissions from the capture system and the baghouse outlet. For more than 75 percent of the time, the opacity was less than 20 percent at the capture point. Readings at the baghouse ranged from 0 to 5 percent. The test data are in Appendix A.

3.1.2 Control of Blasting Operations

No effective method is available for controlling particulate emissions from blasting. Good blasting practices can minimize noise, vibration, and air shock. Multidelay detonation devices, which detonate the explosive charges in millisecond time intervals, can reduce these effects. Scheduling blasting operations so that they occur only during conditions of low wind and low inversion potential can substantially reduce the impact of emissions from this source.

3.1.3 Control of Quarry Loading Operations

Particulate emissions from the loading of broken rock by loaders or shovels are estimated to be 0.025 kg/Mg of stone (0.05 lb/ton). These emissions are difficult to control. However, some control may be attained by using water trucks equipped with hoses or portable watering systems to wet down the piles prior to loading.

3.1.4 Control of Hauling Operations

As indicated in Chapter 2, a large portion of the fugitive dust generated by quarrying operations results from the transportation of broken rock from the quarry to the processing plant over unpaved haul roads. Because haul roads are temporary highways to accommodate advancing quarry faces, they usually are unimproved. Emissions from hauling operations are proportional to the condition of the road surface and the volume and speed of vehicular traffic. Consequently, control measures include methods to improve road surfaces or suppress dust and operational changes to minimize the effect of vehicular traffic.

Various treatment methods applied to control fugitive emissions from haul roads include watering, surface treatment with chemical dust suppressants, soil stabilization, and paving. The most common method is watering. Water is applied to the road in a controlled manner by operators of water trucks equipped with either gravity-fed spray bars or pressure sprays. The amount of water required, frequency of application, and effectiveness are dependent on the weather, the conditions of the roadbed, and the willingness of the operator to allocate the resources required to do an effective job.

On warm and windy days frequent watering may be necessary because of rapid evaporation, whereas after a rainfall it may not be necessary. If watering is excessive, it can create hazardous road conditions for haul vehicles.

Road dust can also be controlled by periodic application of wet or dry surface-treatment chemicals for dust suppression. Road surfaces are commonly treated with oil, usually supplemented by watering. Waste oils such as crankcase drainings are spread over roadways at a rate of about 0.23 liter/m^2 (0.05 gal/yd^2) of roadway.[5] The frequency of application may range from once per week to only several times per season, depending on the temperature, wind, and rainfall in the area. This treatment also must be used judiciously because excessive application can cause slippery, dangerous road conditions.

Other treatments include the application of hygroscopic chemicals (substances that absorb moisture from the air) such as organic sulfonates and calcium chloride ($CaCl_2$). When spread directly over unpaved road surfaces, these chemicals dissolve in the moisture they absorb and form a clear liquid that is resistant to evaporation. Consequently, they are most effective in areas of relatively high humidity. Because the chemicals are water soluble, however, they may have to be applied repeatedly in areas of frequent rainfall. Also, these agents may contribute to the corrosion of expensive haul vehicles.

An alternative to surface treatment is soil stabilization. Stabilizers usually consist of a water dilutable emulsion of either synthetic or petroleum resins that act as an adhesive or binder. Quarry operators in California[6] and Arizona[7] report substantial success with one such agent called Coherex.* This product is a nonvolatile emulsion containing about 60 percent natural petroleum resins and 40 percent wetting solution. The use of Coherex* in the initial treatment of new roads depends on the characteristics of the road bed and the penetration depth required. For most roads, an effective dilution is one part Coherex to four parts of water (1:4) applied at a rate of about 9.1 to 22.7 liters/m^2 (2 to 5 gal/yd^2). Once the road has been stabilized by repeated application and compaction of vehicle traffic over a period of a few weeks, the dilution may be increased to 1:7 to 1:20 for daily maintenance. Detailed data on the application rate are not available; usually one pass per day is considered sufficient for effective dust control. In addition to the environmental benefits obtained by using stabilizers rather than traditional watering methods, considerable savings and operating advantages are reported by users. These include reduced labor costs, lower maintenance costs on haul vehicles, and safer road conditions.

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* The use of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency.

Paving is probably the most effective means of reducing particulate emissions, but the least practical. Initial cost may exceed $20,000/1.61 km ($20,000/mile) for a 76.7-mm (3-in.) bituminous surface, and maintenance and repair costs may be relatively high because of the damage inflicted by heavy vehicle traffic.[8] No study has been made to determine the relative cost-effectiveness of the various control options.

Operational measures that would reduce emissions include the reduction of traffic volume and control of traffic speed. Replacing smaller haul vehicles with larger capacity units would minimize the number of trips required and thus effectively reduce total emissions per ton of rock hauled. A stringent program to control traffic speed would also reduce dust emissions. According to a study of emissions from conventional vehicle traffic on unpaved roads, a reduction in the average vehicle speed from 48 km/h (30 mph) [for which an emission level of 1.68 kg (3.7 lb) per vehicle mile was established] to 40, 32, and 24 km/h (25, 20, and 15 mph) reduced emissions by 25, 33, and 40 percent, respectively.[8] Although the situations may not be completely analogous, it can be concluded that an enforced speed limit of 8 to 16 km/h (5 to 10 mph) would reduce fugitive dust emissions from quarry vehicle traffic and provide additional benefits such as increased safety conditions and longer vehicle life. Additional haul trucks may be required to maintain the production rate. However, the number of trucks required is not determinable because trucks may stand idle while waiting to be loaded.

3.2 CONTROL OF PLANT OPERATIONS

Typical crushed-stone plants contain a multiplicity of dust-producing points, including numerous crushers, screens, conveyor transfer points, and storage facilities. Control methods generally applied to plant-generated emissions include wet dust suppression, dry collection, and a combination of the two. Wet dust suppression consists of introducing moisture into the material flow to restrain fine particulate matter from becoming airborne. Dry collection involves hooding or enclosing dust-producing points and exhausting emissions to a collection device. In combination systems both methods are applied at different stages throughout the process. Completely enclosing process equipment is another very effective technique.

3.2.1 Wet Dust Suppression

In a wet dust-suppression system, dust emissions are controlled by applying moisture to the crushed material at critical dust-producing points in the process flow. This causes dust particles to adhere to large stone surfaces or to form agglomerates too heavy to become or remain airborne. Thus, the objective of wet dust suppression is not to fog an emission source with a fine mist to capture and remove particulates emitted, but rather to prevent their emission by keeping the material moist at all process stages. Excessive moisture can cause blinding of screen surfaces and thereby reduce both their capacity and effectiveness, or it can cause coating of stone surfaces and result in a marginal or nonspecification product. Antifreeze agents may be used during cold temperatures to prevent freezing. Small quantities of specially formulated wetting agents or surfactants are often blended with the water to reduce its surface tension and improve its wetting efficiency so that dust generation may be suppressed with a minimum of "added moisture." Although these agents may vary in composition, their molecules are characteristically composed of two groups, a hydrophobic group (usually a long-chain hydrocarbon) and a hydrophylic group (usually a sulfate, sulfonate, hydroxide, or ethylene oxide). When introduced into untreated water (surface tension 72.75 dynes/cm^2 at 20°C), these agents effect an appreciable reduction in its surface tension (to as low as 27 dynes/cm^3).[9] The dilution of such an agent in water (1 part wetting agent to 1000 parts water) is reported to make dust control effective throughout an entire crushed-stone plant with as little as 1/2 to 1 percent total added moisture per megagram (ton) of stone processed.[10]

In adding moisture to the process flow, it is usually necessary to apply it at several points. Treatment should begin as soon as possible after the material to be processed is introduced into the plant. Normally, the initial application is made at the primary crusher truck dump through the use of spray bars located either on the periphery of the dump hopper or above it. This application significantly reduces intermittent visible dust emissions generated during dumping operations. Applications are also made at the discharge of the primary crusher and all secondary and tertiary crushers where new dry surfaces and dust are generated by the fracturing of stone in the crusher. Treatment may also be required at feeders located under surge or reclaim piles if moisture evaporation from this temporary storage is significant. If the material is conditioned properly at these points, further applications at screens, conveyor transfer points, conveyor and screen discharges to bins, and conveyor discharges to storage piles may not be necessary because moist stone exhibits a carryover dust control effect that permits it to be handled through a number of operations without dusting. The amount of moisture required at each application point depends on the type of wetting agent used and its dilution ratio in water, the type and size of process equipment used, and the characteristics of the material processed (rock type, size distribution, feed rate, and moisture content).

A typical wet dust-suppression system (illustrated in Figure 3-1) contains the following basic components and features: a dust control agent, proportioning equipment, a distribution system, and control actuators. A proportioner and pump are necessary to mix the wetting agent and water at the desired ratio and to provide the moisture in sufficient quantity and at adequate pressure to meet the demands of the overall system.

Distribution is accomplished by spray headers fitted with pressure spray nozzles. One or more headers are used to apply the dust-suppressant mixture at each treatment point at the rate and spray configuration required to control the dust effectively. The nozzle type used, hollow-cone, solid cone, or fan, depends on the spray pattern desired. Screen filters are used to prevent nozzle plugging. Figure 3-2 shows a typical arrangement for the control of dust emissions at a crusher discharge.

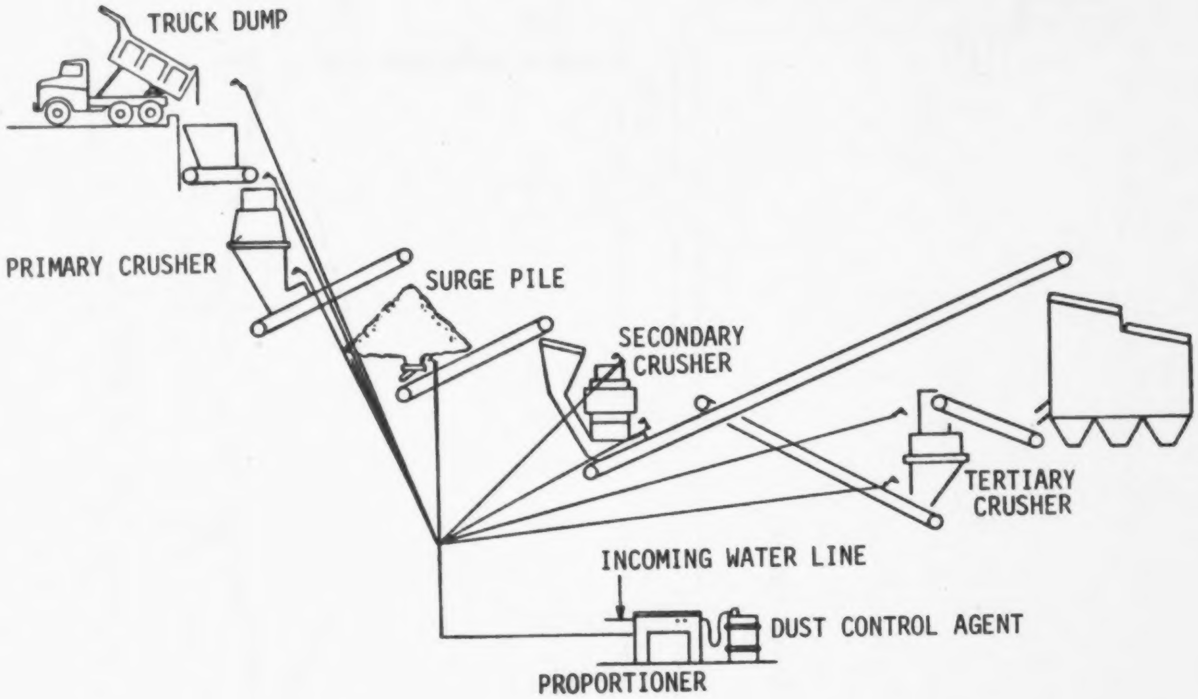
TRUCK DUMP
PRIMARY CRUSHER
SURGE PILE
SECONDARY CRUSHER
TERTIARY CRUSHER
INCOMING WATER LINE
DUST CONTROL AGENT
PROPORTIONER

Figure 3-1. Wet dust-suppression system.[11]

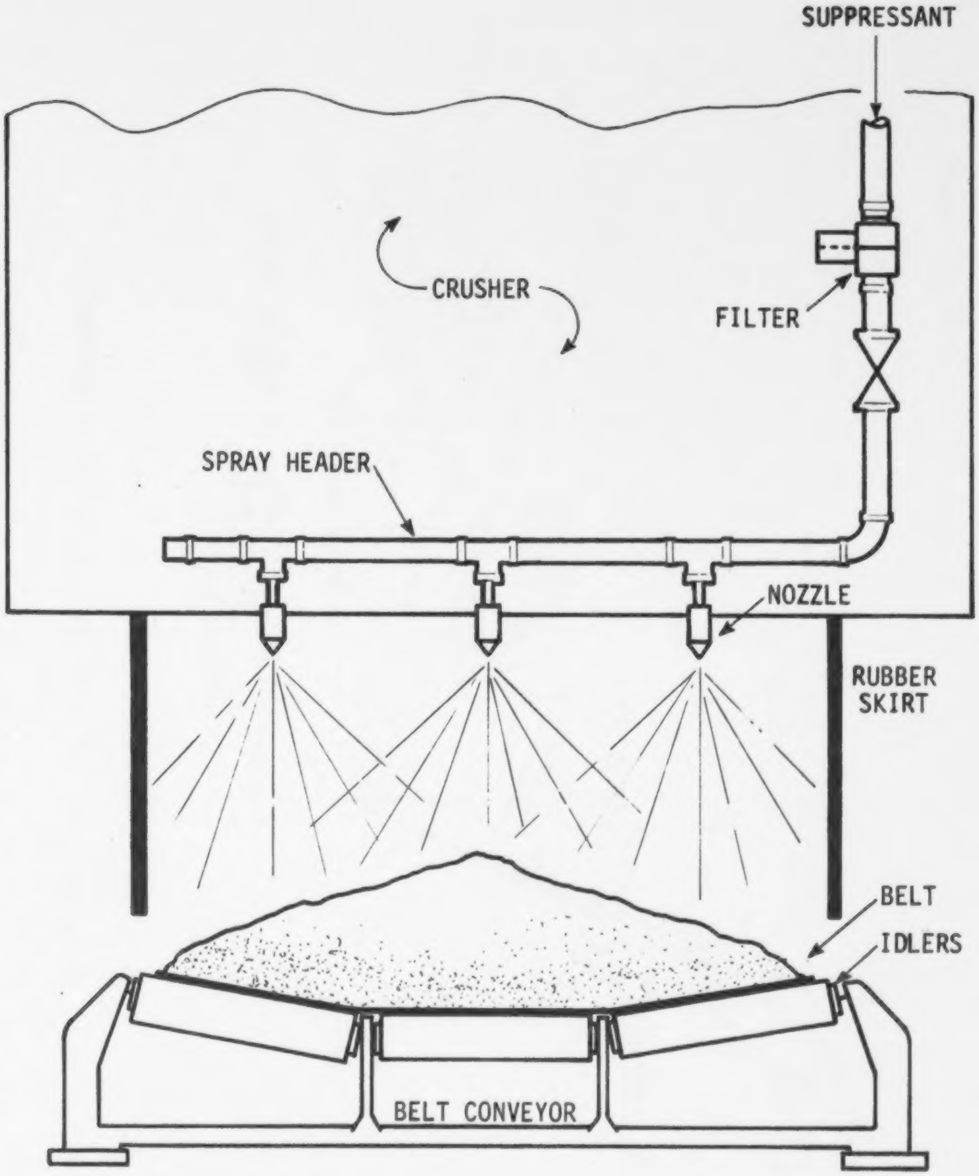
SUPPRESSANT
CRUSHER
FILTER
SPRAY HEADER
NOZZLE
RUBBER SKIRT
BELT
IDLERS
BELT CONVEYOR

Figure 3-2. Dust suppression application at crusher discharge.

Spray actuation and control are important to achieve effective control and to reduce waste and undesirable muddy conditions, especially when the material flow is intermittent. Spray headers at each application point are normally equipped with an on-off controller that is interlocked with a sensing mechanism so that sprays will be operative only when material is flowing. Systems are also commonly designed to operate under all weather conditions. Exposed pipes are usually traced with heating wire and insulated to provide protection from freezing.

One manufacturer claims emissions can be controlled at better than 90 percent efficiency from primary crusher to stockpile with a well-designed wet dust-suppression system.[10] Because these unconstrained emissions cannot be tested, no actual particulate emission measurements have been made to verify or dispute this contention.

3.2.2 Dry Collection Systems

Particulate emissions generated at plant facilities (crushers, screens, conveyor transfer points, and bins) may be controlled by capturing and exhausting emissions to a collection device. Depending on the physical layout of the plant, emission sources may be manifolded to one centrally located collector or to strategically placed units. Collection systems consist of hoods and enclosures to confine and capture emissions and ducting and fans to convey the captured emissions to a collection device where they are removed before the airstream is exhausted to the atmosphere.

Exhaust Systems --

If a collection system is to effectively prevent particulate emissions from being discharged to the atmosphere, its hooding and ducting must be properly designed and balanced. Process equipment should be enclosed as completely as practicable, yet allow access room for routine maintenance and inspection requirements. For crushed-stone facilities, recommended hood face or capture velocities may range from 1 to 2.5 m/s (200 to 500 ft/min).[12] In general, a minimum indraft velocity of 1 m/s (200 ft/min) should be maintained through all open hood areas. Properly designed hoods and enclosures minimize exhaust volume and, consequently, power requirements. Proper hooding will also minimize the effects of cross drafts (wind) and the effects of induced air (i.e., air placed in motion as a result of machine movement or falling material). Good duct design dictates that adequate conveying velocities be maintained so that the transported dust particles will not settle in the ducts along the way to the collection device. Conveying velocities recommended for crushed-stone particles range from 17.8 to 22.9 m/s (3500 to 4500 ft/min).[12]

Completely adequate construction specifications are available and have been utilized to produce efficient, longlasting systems. Various guidelines have been established for minimum ventilation rates required to control emissions from crushing plant facilities. The following are ventilation rates most commonly utilized in the industry, based upon these guidelines.

Conveyor transfer points --

At belt-to-belt conveyor transfer points, hoods should be designed to enclose both the head pulley of the upper belt and the tail pulley of the lower belt as completely as possible. The open area should be reduced to about 0.152 m^2/m (0.5 ft^2/ft) of belt width to achieve the proper design.[13] Air volume to be exhausted is affected by conveyor belt speed and free-fall distance to which the material is subjected. Recommended exhaust rates are 0.55 m^3/s per m (350 ft^3/min per ft) of belt width for belt speeds less than 1.0 m/s (200 ft/min) and 0.24 m^3/s (500 ft^3/min) for belt speeds exceeding 1.0 m/s (200 ft/min).[14] For a belt-to-belt transfer with less than a 0.91 m (3 ft) fall, the enclosure illustrated in Figure 3-3 is commonly used.

For belt-to-belt transfers with a free-fall distance greater than 0.91 m (3 ft) and for chute-to-belt transfers, an arrangement similar to that depicted in Figure 3-4 is commonly used. The exhaust connection should be made as far downstream as possible to maximize dust fallout and thereby minimize needless dust entrainment. For very dusty material,

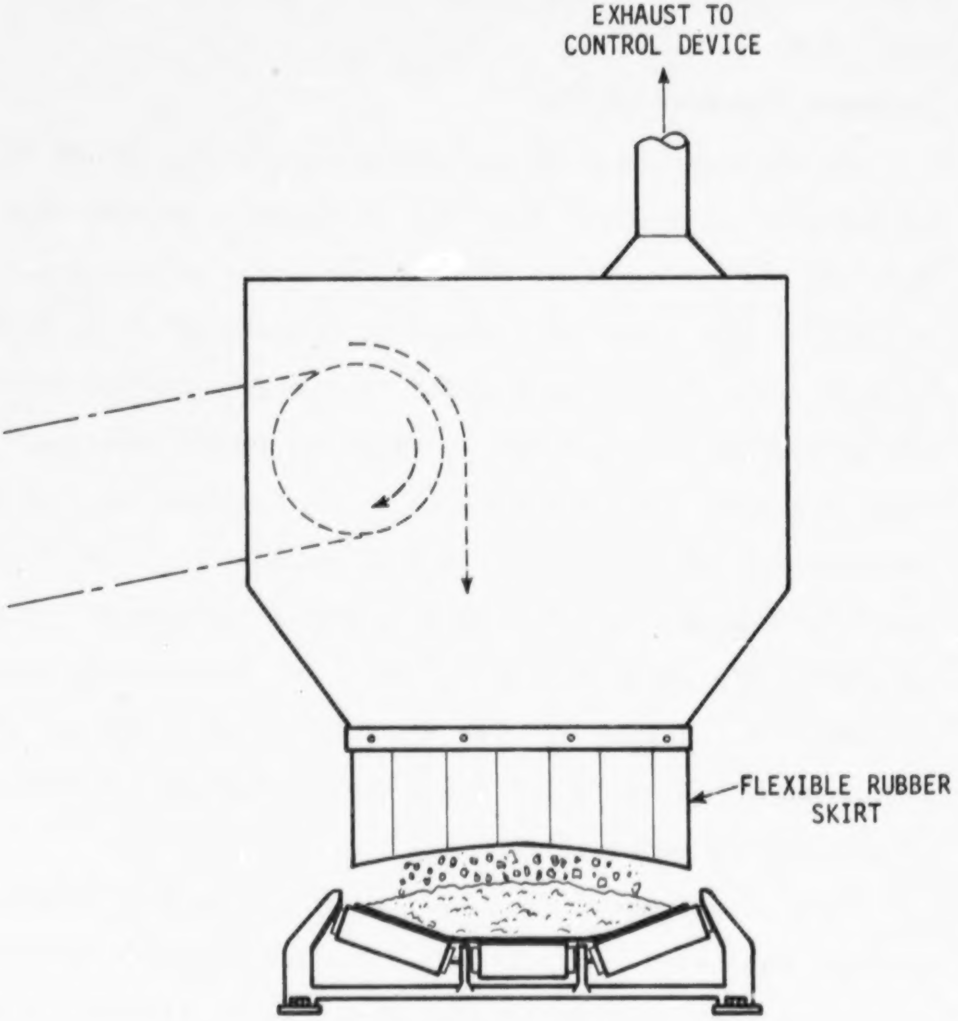
EXHAUST TO
CONTROL DEVICE
FLEXIBLE RUBBER
SKIRT

Figure 3-3. Hood configuration for a transfer point having a fall less than 0.91 m (3 ft).

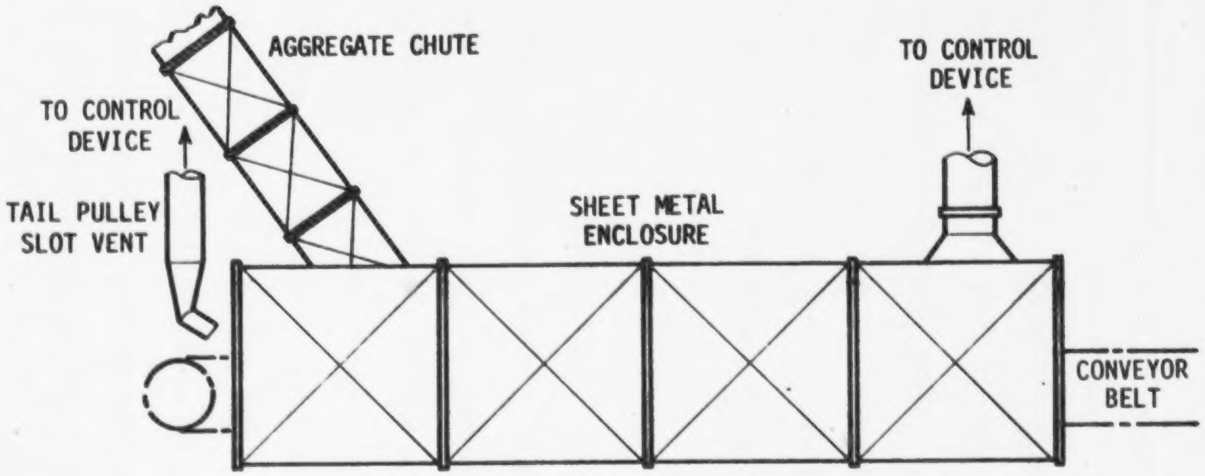
AGGREGATE CHUTE
TO CONTROL DEVICE
TAIL PULLEY SLOT VENT
SHEET METAL ENCLOSURE
TO CONTROL DEVICE
CONVEYOR BELT

Figure 3-4. Hood configuration for a transfer point having a fall greater than 0.91 m (3 ft).

additional exhaust air may be required at the tail pulley of the receiving belt. Recommended air volumes are 0.33 m^3/s (700 ft^3/min) for belts 0.91 m (3 ft) wide and less, and 0.47 m^3/s (1000 ft^3/min) for belts wider than 0.91 m (3 ft).[14]

Transfers from belt or chute to bin differ from the usual transfer operation in that no open area is downstream of the transfer point. Thus emissions occur only at the loading point. At some point, normally remote from the loading point, air is exhausted from the bin at a minimum rate of 0.094 m^3/s (200 ft^3/min) per ft^2 of open area at the loading point.[14]

Screens --

Screening surfaces can be fully hooded to control emissions. The exhaust volume required varies with the surface area of the screen and the amount of open area between the screen and its enclosure. A well-designed enclosure should have no more than 50.8 to 101.6 mm (2 to 4 in.) of space around the periphery of the screen. A minimum exhaust rate of 0.25 m^3/s per m^2 (50 ft^3/min per ft^2) of screen area is commonly used, with no increase for multiple decks.[14] Oversize discharge points that require additional ventilation should be treated as regular transfer points and exhausted accordingly.

Crushers --

Hooding and air volume requirements for the control of crushers are quite variable. The only established criterion is that a minimum indraft velocity of 1.0 m/s (200 ft/min) be maintained through all open hood areas. To achieve this, control velocities in excess of 2.5 m/s (500 ft/min) may be necessary to overcome induced air movement resulting from the material flow and mechanical motion.[13] For effective control of emissions, ventilation should be applied at both feed and discharge points of the crusher. An exception to this would be at primary jaw or gyratory crushers because it is necessary to have ready access to the crusher feed opening to dislodge large rocks that may get stuck. No plant is known to use a baghouse at this point.

In general, crusher feed should be enclosed as completely as possible and exhausted according to the criterion established for transfer points. The crusher discharge to the conveyor belt should also be totally enclosed. The exhaust rate, however, may vary considerably depending on crusher type. For impact crushers, exhaust volumes may range from 1.88 to 3.76 m^3/s (4000 to 8000 ft^3/min).[15] For compression-type crushers, an exhaust rate of 0.78 m^3/s per m (500 ft^3/min per ft) of discharge opening should be sufficient.[15] In either case, pickup should be applied downstream of the crusher at a distance of at least 3.5 multiplied by the width of the receiving conveyor.[15]

Collection Devices --

The most commonly used dust collection device in the crushed-stone industry is the fabric filter, or baghouse. Fabric filters are used for most crushing plant applications. The fabric filters that are equipped with a mechanical shaker require periodic shutdown for cleaning every 4 or 5 hours of operation. These units, normally equipped with cotton sateen bags, are operated at an air-to-cloth ratio ranging from 2:1 to 3:1. A cleaning cycle, which requires no more than 2 to 3 minutes of bag shaking, is normally actuated when the plant is not operating.

If it is impractical to turn off the collector, fabric filters with continuous cleaning are employed. Although compartmented, mechanical-shaker types may be used, jet-pulse units are preferred. These units usually use a filtering medium of wool or synthetic felt, and they may be operated at filtering ratios as high as 6:1 to 10:1. With either type of baghouse, greater than 99 percent efficiency can be attained, even on submicron particle sizes.[3] During EPA emission tests at a variety of crushed-stone facilities, outlet grain loadings were seldom recorded in excess of 0.023 g/dry m^3 (0.01 gr/dscf). (See Section 3.5 and Appendix A for details.)

Other collection devices used in the industry include cyclones and low-energy scrubbers. Although these collectors may demonstrate high efficiencies (95 to 99 percent) for coarse particles (40 μm and larger), they are less efficient for medium and fine particles (20 μm and smaller).[3] Although high-energy scrubbers and electrostatic precipitators could conceivably achieve results similar to those of a fabric filter, these devices are not used currently in the industry.

3.2.3 Combination Control Systems

Wet dust-suppression and dry collection techniques are often used in combination to control particulate emissions from crushed stone facilities. As illustrated in Figure 3-5, wet dust-suppression techniques are generally used to control emissions at the primary crushing stage and at subsequent screens, transfer points, and crusher feeds. Dry collection is generally used to control emissions at secondary and tertiary crusher discharges, where new dry stone surfaces and fine particulates are formed. A large portion of the fine particulates is removed by dry collection, but subsequent dust suppression applications become more effective with a minimum of added moisture. Depending on the production requirements, dry collection may be the only method that can be used at the finishing screens.

3.2.4 Control of Portable Plants

Control of emissions from a portable plant is difficult compared with that from a stationary one. However, minimal

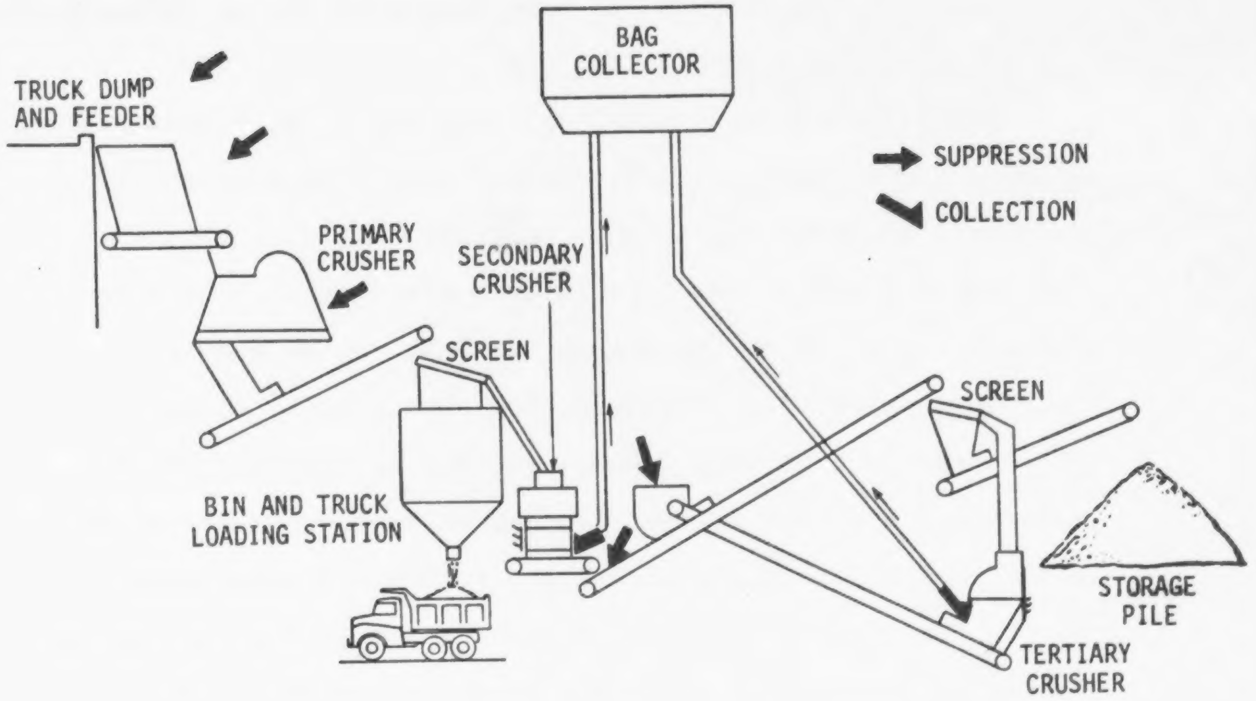
BAG COLLECTOR
TRUCK DUMP AND FEEDER
SUPPRESSION
COLLECTION
PRIMARY CRUSHER
SECONDARY CRUSHER
SCREEN
SCREEN
BIN AND TRUCK LOADING STATION
STORAGE PILE
TERTIARY CRUSHER

Figure 3-5. Combination control system.[11]

visible emissions have been reported from the successful application of a wet dust-suppression system.[16] Also, trailer-mounted portable baghouse units are commercially available and have been applied to control emissions from portable plants. In Pennsylvania, most portable plants use a wet dust-suppression system.[17]

3.3 CONTROL OF FUGITIVE DUST SOURCE

Uncontrolled fugitive dust emissions constitute a significant portion of the pollution problem in the crushed-stone industry. Control measures to reduce fugitive dust emissions from quarrying operations (blasting, loading, and hauling) were discussed in Section 3.1. A review of the control measures applied to other fugitive sources is presented here.

3.3.1 Control of Aggregate Storage Piles

Significant fugitive dust emissions, as judged by visible emissions, may result during the formation of new aggregate piles and the erosion of previously formed piles. During the formation of stockpiles by stacking conveyors, particulate emissions are generated by wind blowing across the streams of falling stone and segregating fine particles from coarse particles. Emissions are also produced when the falling stone impacts on the piles. Control methods include wet dust suppression and devices designed to minimize the free-fall distance to which the material is subjected, thus lessening its exposure to wind and reducing emissions generated upon impact.

The wet dust-suppression effect is carried over at plants that spray the discharge from the final crushing or screening operation, after which no new surfaces are created nor the material tumbled. Control devices that are applied include stone ladders, telescopic chutes, and hinged-boom stacker conveyors. A stone ladder simply consists of a section of vertical pipe into which stone from the stacking conveyor is discharged. At different levels the pipe has square or rectangular openings through which the material may flow. This reduces the effective free-fall distance and affords wind protection. Another approach is the telescopic chute. Material is discharged to a retractable chute and falls freely to the top of the pile. As the height of the stockpile increases or decreases, the chute is gradually raised or lowered accordingly. A similar approach is provided by a stacker conveyor equipped with an adjustable hinged boom that raises or lowers the conveyor according to the height of the stockpile.

Watering is the most commonly used technique for controlling windblown emissions from active stockpiles. A water truck equipped with a hose or other spray device may be used. One operator uses spray towers in the stockpile areas. The towers are equipped with Rainbird*-type spray nozzles capable of spraying water at 31.6 liters/s (500 gal/min) in a continuous circle with a 61.0 m (200 ft) radius. Only three passes are required to effectively wet down a pile.[5]

Locating stockpiles behind natural or manufactured windbreaks also aids in reducing windblown dust. Also, the working area of active piles should be located on the leeward side of the pile. Very fine materials or materials that must be stored dry can be controlled effectively only through the use of suitable stockpile enclosures or silos, even though these may create load-out problems.

The application of soil stabilizers, which are primarily petroleum or synthetic resins in emulsion, has been reasonably effective for storage piles that are inactive for long periods of time and for permanent waste piles or spoil banks. These chemical binders cause the surface particles to adhere to one another, forming a durable wind and rain resistant crust (relatively insoluble in water). As long as this crust remains intact, the stockpile is protected from wind erosion.

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* Mention of company product names is not to be considered as an endorsement by the U.S. Environmental Protection Agency.

3.3.2 Control of Conveying Operations

In addition to the emissions generated at transfer points, fugitive dust emissions may result from conveying operations.

Dust-control alternatives include chemical suppression and covering. As noted in Section 3.2.1, a carryover, dust-proofing effect will result from previous applications of dust suppressants. It is unlikely, however, that this carryover effect is sufficient to afford effective control during periods of high wind and low humidity or when handling fine materials. Ultimately, the most effective measure is to cover open conveyors because covers provide protection from wind and an opportunity for airborne particles to fall out. In addition to providing dust control, covered conveyors also yield certain operating benefits. They increase a plant's capability to operate during periods of inclement weather by reducing the potential for mud cake buildup on belts. This buildup can damage conveyors and result in hazardous operating conditions, screen blinding, and the production of nonspecification products as a result of the retention of fines. Conveyor covers must be removed during conveyor breakdowns, which are rare.

3.3.3 Control of Load Out Operations

The transfer of fine materials from stockpiles or storage bins into open dump trucks may generate significant fugitive dust emissions as judged by visible emissions. These operations are currently uncontrolled except for some attempts to wet the material either prior to or during loading. Dust formation may be reduced if the stone is kept wet on the stockpiles and the loaded buckets are emptied as close as possible to the truck beds.

At some installations, water spray systems are used to wet the stone in the truck when loading out of bins. Enclosing the area under the bins as much as possible will also reduce the potential for windblown emissions. In concrete-batch plants, exhaust systems with canopy type hoods are sometimes applied to control dust emissions from bin load-out operations. In concrete-batch plants, exhaust systems with canopy type hoods are sometimes applied to control dust emissions from bin load-out operations; however, no such application has been found in the crushed-stone industry. Operators contend that such a system would be impractical because of the variability in the bed size of the trucks loaded.

3.3.4 Control of Yard and Other Open Areas

Fugitive dust emissions from plant yard areas are generated by vehicular traffic and wind. These emissions generally are not controlled at crushed-stone plants. Emissions from these areas can be controlled by maintaining good housekeeping practices. Spillage and other potential dust sources should be cleaned up. Street-sweeping equipment has been effective for paved or other smooth yard surfaces. The same control measures applied to quarry haul roads can be used for intraplant roads subject to high traffic volume. Treatment with soil stabilizers and planting of vegetation offer viable control options for large open areas and overburden piles. Many chemical stabilizers presently on the market promote the growth of vegetation and offer effective control against rain and wind erosion.[18]

3.4 FACTORS AFFECTING THE PERFORMANCE OF CONTROL SYSTEMS

3.4.1 Dust Suppression

Factors that may affect the performance of a wet dust-suppression system include the particular wetting agent used, the method of application, characteristics of the process flow, and the type and size of the process equipment serviced. The number, type, and configuration of spray nozzles at an application point, as well as the speed at which a material stream moves past that point, may affect both the efficiency and uniformity of wetting. Meteorological factors such as wind, ambient temperature, and humidity, which affect the evaporation rate of added moisture, may also adversely affect the overall performance of a dust-suppression system. When the material processed contains a high percentage of fines, such as the product from a hammermill, dust-suppression applications may be essentially inefffective because of the enormous surface area to be treated.

3.4.2 Dry Collection

In dry collection systems, factors affecting both capture and collection efficiency are important. Wind blowing through hood openings can significantly reduce the effectiveness of a local exhaust system. This is significant because an indraft velocity of 1 m/s (200 ft/min) is equivalent to less than 3.7 km/h (2.3 m/h); consequently, it may be necessary to enclose process equipment at installations that are subject to buffeting by high prevailing winds.

An exhaust system must be properly maintained and balanced if it is to remain effective. Good practice dictates that systems be periodically inspected and that capture and conveying velocities be checked against design specifications to assure that the system is functioning properly. Abrasion which produces leaks and poorly designed ducts that permit material to accumulate are the two primary causes of unbalanced flow in an exhaust system.

Bag cleaning has a significant effect on performance. Inadequate cleaning causes fabric filters to blind, resulting in excessively high pressure drops. Cleaning too frequently or too vigorously results in excessive bag wear and the formation of leaks. Overcleaning may also prevent the formation of an adequate filter cake and, thus, lowers the collection efficiency. The importance of following manufacturers' recommended operating and maintenance procedures cannot be overstressed.

Emission tests were carried out by EPA on 12 baghouse units at seven crushed-stone installations that process a variety of rock types, including limestone, traprock, and cement rock. These tests indicated that the size distribution of particulates collected, the rock type processed, and the facilities controlled (crushers, screens, and transfer points) do not substantially affect baghouse performance (see Appendix A - Source Test Data).

3.4.3 Combination Systems

Factors affecting the performance of combination systems are identical to those encountered when dust-suppression or collection systems are used alone.

3.4.4 Retrofit Control Systems

Space availability is a major factor in retrofitting a control system. Often, little space is available at plants located in urban or congested areas. Space limitation is not a problem for crushed-stone plants, except that some existing plants may require longer duct runs.

Other major factors affecting retrofit are the availability of utilities (electricity and water) and any required modifications to the existing plant. Little plant modification is required for retrofitting wet dust-suppression systems or dry collection systems to existing crushed-stone plants. Very little additional power is required for wet dust-suppression systems. Dry collection systems may require up to 22 percent additional power. Additional generators may have to be installed at portable plants to meet this demand.

Retrofit systems generally require more engineering time than would be required for incorporating a control system into a new installation. Because construction equipment and labor are brought in just for installing the control system, the installation costs are high. In addition, a loss of production occurs during retrofitting. Crushed-stone plants that operate seasonally may be able to schedule retrofitting during the off season. The most important consideration in retrofitting, from a cost standpoint, is the remaining plant life. Control equipment costs are presented in Chapter 4.

A spokesman for a company that operates a number of plants stated that they did not experience any special problems in retrofitting wet dust-suppression or dry collection systems.[19] Pennsylvania State Agency personnel have not reported any special complaints, except that longer duct runs are required in some cases.[17]

3.5 PERFORMANCE DATA ON PARTICULATE EMISSION CONTROL SYSTEMS[21]

3.5.1 Dry Collection Systems

Particulate Emission Data --

Particulate emission measurements were conducted by EPA on 12 baghouse collectors used to control emissions generated at crushing, screening, and conveying transfer points at five crushed-stone installations. Measurements were also conducted on a baghouse unit that serves a drilling operation at a limestone quarry. Table 3-2 briefly summarizes the process facilities controlled by each baghouse tested. Appendix A contains complete test data summaries for both mass particulate measurements and visible emission observations and a description of each process facility tested.

Of the five plants tested, three processed limestone rock (A, B, and C) and two processed traprock (D and E). Four of the five were commercial crushed-stone operations producing a variety of end products including dense-graded road base stone, bituminous aggregates, concrete aggregates and nonspecific construction aggregates. In addition, plant B produced about 60 tons/h of agstone. Facilities

Table 3-2. PROCESS FACILITIES CONTROLLED BY BAGHOUSE UNITS TESTED

Facility	Rock type processed	Baghouse specifications			Process facilities controlled
		Type	Filtering Ratio	Capacity, Nm^3/s (scfm)	
A1	Limestone	Jet Pulse	5.3 to 1	12.44 (26472)	Primary impact crusher
A2	Limestone	Jet Pulse	7 to 1	7.43 (15811)	Primary screen
A3	Limestone	Jet Pulse	7 to 1	1.10 (2346)	Conveyor transfer point
A4	Limestone	Jet Pulse	5.2 to 1	4.95 (10532)	Secondary crusher (cone) and screen
B1	Limestone	Shaker	3.1 to 1	2.72 (5784)	Primary impact crusher
B2	Limestone	Shaker	2.1 to 1	8.55 (18197)	Scalping screen, secondary cone crusher, hammer mill, two teriary cone crushers, two finishing screens, five storage bins, and six conveyor transfer points
C1	Limestone	Shaker	2.3 to 1	3.51 (7473)	Primary jaw crusher (discharge), scalping screen, and hammer mill
C2	Limestone	Shaker	2.0 to 1	3.08 (6543)	Two finishing screens and two conveyor transfer points
D1	Traprock	Shaker	2.8 to 1	14.98 (31863)	Scalping screen, secondary cone crusher, two sizing screens, two tertiary cone crushers, and several conveyor transfer points
D2	Traprock	Shaker	2.8 to 1	12.20 (25960)	Finishing screen and several conveyor transfer points
E1	Traprock	Jet Pulse	5.2 to 1	6.93 (14748)	Two sizing screens, four teriary cone crushers, and several conveyor transfer points
E2	Traprock	Jet Pulse	7.5 to 1	9.93 (2122)	Five finishing screens and eight storage bins
F	Limestone	Shaker	2.5 to 1	0.31 (663)	Rotary drill

A1 through A4 consist of process operations producing raw material for the manufacture of portland cement. Facilities A1 and B1 are both impact crushers used for the primary crushing of run-of-quarry limestone rock. Facility A3 is somewhat unique in that it consists of a single conveyor transfer point at the tail of an overland conveyor. As indicated in Table 3-2, the remaining facilities tested consisted of multiple secondary and teriary crushing and screening operations, and adjunct conveyor transfer points. These include one primary jaw crusher, three secondary cone crushers, two hammer mills, eight teriary cone crushers, 19 screens, 13 product bins, and over 15 conveyor transfer points.

The baghouses tested included both jet pulse and mechanical shaker type units. In all cases, the shaker type fabric filters used cotton sateen bags and were operated at a 2:1 to 3:1 filtering ratio. The jet pulse units tested were fitted with wool or synthetic fiber belted bags. Air to cloth ratios ranged from about 5:1 to 7.5:1.

A minimum of three test runs, using EPA Method 5, were conducted at each facility tested. Sampling was performed only during periods of normal operation and was stopped and restarted to allow for intermittent process shutdowns and upsets (no stone). When the process weight rate was undeterminable at a specific process facility, as in most instances, the process weight through the primary crushing stage was monitored to assure that the plant was operating at or near normal capacity. Moisture determinations on the stone processed were also performed at each plant tested (except for plant A) to ensure that control was effected by the dust collection system and not moisture inherent in the material processed. Each test run at Facility F was conducted to coincide with the time required to drill one blast hole.

Excluding the measurements made at Facility F, the emission concentration of the control devices tested averaged 0.011 g/dry m^3 (0.005 gr/dscf) and never exceeded 0.030 g/dry m^2 (0.013 gr/dscf). The results of the measurements performed at Facility F (rotary drill) averaged 0.089 g/dry m^3 (0.039 gr/dscf). It is suspected that because this collector utilized a manually operated shaker mechanism for cleaning, it may have been subjected to overcleaning and, consequently, poor filter cake buildup.

Visible Emissions Data --

Visible emission observations were also made during the emission tests previously described. The exhaust from each of the fabric filters tested was observed for about 4 hours in accordance with EPA Method 9 procedures. No visible emissions were observed from the fabric filters at plants A, C, D, and E. Slight emissions ranging from 0 to 5 percent opacity were observed at B1, B2, and F. The highest 6-minute average recorded at each of these facilities was 1.0, 0.8, and 4.2 percent opacity, respectively. Again, the performance level achieved by the baghouse servicing facility F (rotary drill) is suspect.

Observations of visible emissions were also made at the capture hoods and enclosures installed on many of the process facilities controlled by the baghouses tested at plants A, B and D to determine the presence and opacity of emissions escaping capture. Eight crushers, six screens, one conveyor transfer point and one surge bin were observed at plants A, B and D. Again, EPA Reference Method 9 was used. Table 3-3 lists the specific process facilities observed and summarizes the results obtained in terms of the percent of time over a stated observation period that visible emissions occurred. Complete data summaries are contained in Appendix A. In most cases essentially no visible emissions were observed at adequately hooded or enclosed process facilities. Where emissions were observed, they were of short duration and seldom exceeded five percent opacity.

As shown in Table 3-3, no visible emissions were observed at six of the eight crushers at which visual observations were made. The six crushers include a hammermill used to produce agricultural limestone at plant B and five cone crushers used for secondary and tertiary crushing at plants B and D. Visible emissions at the remaining two crushers, which include a primary impactor at plant A and a secondary cone crusher at plant B, were observed less than 2 percent of the time and 10 percent of the time respectively.

TABLE 3-3 SUMMARY OF VISIBLE EMISSION OBSERVATIONS AT CAPTURE HOODS OR ENCLOSURES ON CRUSHED-STONE PLANT PROCESS FACILITIES

Plant/Rock type processed	Process facility	Accumulated observation time (minutes)	Accumulated emission time (minutes)	Percent of time with visible emissions
A Crushed limestone	Primary impact crusher discharge	240	4	2
	Conveyor transfer point	166	3	3
B Crushed limestone	Scalping screen	287	45	15
	Surge bin	287	3	1
	Secondary cone crusher No. 1	231	23	10
	Secondary cone crusher No. 2	231	0	0
	Secondary cone crusher No. 3	231	0	0
	Hammer mill	287	0	0
	3-deck finishing screen (L)	107	4	4
	3-deck finishing screen (R)	107	0	0
D Crushed stone	No. 1 tertiary gyrasphere cone crusher	170	0	0
	No. 2 tertiary gyrasphere cone crusher	170	0	0
	Secondary standard cone crusher	170	0	0
	Scalping screen	210	0	0
	Secondary (2-deck) sizing screen	210	0	0
	Secondary (3-deck) sizing screen	210	0	0

At the six screens at which visual observations were made, no visible emissions were observed at four and only slight emissions (less than 4 percent of the time) were observed at the fifth. At the sixth screen (scalping screen at plant B), emissions were observed 15 percent of the time. When present, visible emissions at the scalping screen were primarily observed in the area of the shaker-drive motor rather than at the actual screening surface. Emissions were recorded at the conveyor or transfer point at plant A and the surge bin at plant B were also slight, ranging from 3 to 4 percent of time.

WET DUST SUPPRESSION

Due to the unconfined nature of emissions from facilities controlled by wet dust suppression techniques, the quantitative measurement of mass particulate emissions at these facilities is impractical. However, some assessment of the effectiveness of this technique can be made by visual observation.

Visual observations were made at numerous process facilities at five installations where particulate emissions generated are controlled by wet dust suppression techniques. The installations included two portable plants (I and K) and three stationary plants (G, H and J). Visual observations were made using both EPA Reference Methods 9 and 22. The process facilities observed included 12 crushers, 11 screens, 8 transfer points and 1 storage bin. A summary of the results is presented in Table 3-4.

The results obtained indicate that emissions from crushers are generally greater than those from non-crusher sources.

TABLE 3 - 4
SUMMARY OF VISIBLE EMISSION OBSERVATIONS FROM CRUSHED STONE PROCESS FACILITIES CONTROLLED BY WET DUST SUPPRESSION

Plant	Process Facilities	EPA Method 22 Observation time (minutes)	EPA Method 22 Percent of time Emissions visible	EPA Method 9 Observation time (minutes)	EPA Method 9 Highest Six-Minute Average	Average Opacity
G	Primary Jaw Crusher	20	69	102	21	11
	Scalping Screen	--	--	60	12	10
	Secondary Impact Crusher	20	96	60	15	11
	Secondary Screen	60	0	60	0	0
	Tertiary Cone Crusher	--	--	120	25	13
	Conveyor Transfer Point	60	1	60	3	< 1
H	Primary Jaw Crusher	60	53	120	18	8
	Scalping Screen	60	36	120	10	4
	Conveyor Transfer Point	60	49	120	14	9
	Secondary Screen	120	0	120	2	1
	Secondary Cone Crusher	30	95	120	39	26
	Finishing Screens	120	0	120	< 1	0
I	Scalping Screen	120	3	120	3	2
	Primary Jaw Crusher	30	93	120	17	11
	Conveyor Transfer Point	30	12	60	5	2
	Secondary Screens	120	9	120	5	1
	Secondary Cone Crusher	30	99	120	17	14
	Finishing Screens	120	0	120	1	< 1
	Conveyor Transfer Point	60	0	60	0	0
	Conveyor Transfer Point	60	2	60	3	< 1
J	Primary Jaw Crusher	60	5	120	3	1
	Scalping Screen (2-deck)	120	0	120	0	0
	Secondary Cone Crusher (4 1/2')	30	68	120	5	4
	Secondary Screen	120	10	120	4	< 1
	Secondary Cone Crusher (5 1/2')	30	25	120	15	8
	Conveyor Transfer Point	120	0	120	0	0
	Conveyor Transfer Point	120	0	120	0	0
K	Primary Jaw Crusher	30	65	120	11	8
	Conveyor Transfer Point	120	2	120	4	< 1
	Secondary Screen (3-deck)	120	0	120	0	0
	Secondary Cone Crusher (4 1/4')	30	100	120	23	17
	Storage Bin	120	0	120	2	< 1

Visual observations made at twelve crushers including jaw, impact and cone type crushers showed that emissions were generally continuous (visible about 70 percent of the time on average) and typically exceeded 10 percent opacity. In contrast, emissions from non-crusher sources (screens and conveyor transfer points) were generally intermittent (visible less than 90 percent of the time) and seldom exceeded five percent opacity.

Excluding the scalping screen and conveyor transfer point observed at plant G and the scalping screen observed at plant H, which were judged to have inadequate controls, the highest six-minute average recorded using EPA Method 9 at non-crusher sources was 5 percent. In general, the wet dust suppression controls applied at the majority of crusher sources observed were judged to be inadequate due to the poor positioning of spray bars or the use of too few nozzles. In fact, of the 12 crushers observed, only the primary jaw crusher and secondary cone crushers at plant J and the primary jaw crushers at plants G and K were judged to have adequate controls with the highest six-minute average recorded equalling 15 percent opacity.

3.5.3 Combination Control Systems

Performance levels of combination systems are identical to those when dust-suppression or collection systems are used alone.

3.5.4 Fugitive Dust Control Measures

No procedures are available for quantifying emissions from fugitive dust sources. No visible emission test programs were conducted during this study.

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4.0 COSTS OF APPLYING THE TECHNOLOGY

The crushed-stone industry produces a high volume of a low-value commodity. It is the largest nonfuel, nonmetallic mineral industry in the United States with respect to both total volume and value of production. Total production in 1977 was 829 million Mg (914 million short tons), valued at over 2.2 billion dollars.[1] Geographically, the industry is highly dispersed, with all states except Delaware reporting production. Section 4.1 describes the industry in terms of types of products, production capacities, and average production costs.

Sections 4.2 and 4.3 present investment and annual cost estimates for controlling process and fugitive dust sources, respectively. Unless stated otherwise, all costs are for December 1976.

4.1 INDUSTRY CHARACTERIZATION

Table 4-1 lists according to size the number of crushed-stone quarries operating in 1973 and indicates the amount of production in each range. The distribution of production among individual quarries is not uniform and ranges from

Table 4-1. NUMBER AND PRODUCTION OF QUARRIES BY SIZE IN 1976[a]

Annual production, Mg	Annual production, short tons	Number of quarries	Percent of total	Production: Thousand megagrams	Production: Thousand short tons	Percent of total
Less than 22,676	(Less than 25,000)	2030	38.9	13,227	(14,583)	1.6
22,676 to 45,350	(25,000 to 49,999)	705	13.5	22,843	(25,184)	2.8
45,351 to 68,026	(50,000 to 74,999)	320	6.2	17,911	(19,747)	2.2
68,027 to 90,702	(75,000 to 99,999)	253	4.9	19,859	(21,894)	2.4
90,703 to 181,405	(100,000 to 199,999)	668	12.8	84,910	(93,613)	10.4
181,405 to 272,108	(200,000 to 299,999)	368	7.1	81,251	(89,579)	9.9
272,109 to 362,811	(300,000 to 399,999)	215	4.1	66,849	(73,701)	8.2
362,812 to 453,514	(400,000 to 499,999)	177	3.4	70,898	(78,165)	8.7
453,515 to 544,217	(500,000 t0 599,999)	109	2.1	54,338	(59,908)	6.6
544,218 to 634,919	(600,000 to 699,999)	92	1.8	53,830	(59,348)	6.6
635,920 to 725,623	(700,000 to 799,999)	65	1.2	44,269	(48,807)	5.4
725,624 to 816,326	(800,000 to 899,999)	43	0.8	33,039	(36,425)	4.0
816,327 and over	(900,000 and over)	169	3.2	253,016	(278,950)	31.0
Total		5214	100.0	816,562	900,260	100.0

[a] Minerals Yearbook, 1976. Bureau of Mines.

less than 22,676 Mg (25,000 tons) to several million megagrams (tons) per year. Of the 5214 quarries worked in 1976, those with an annual production of less than 22,676 Mg (25,000 tons) represented 38.9 percent of the total number, yet accounted for only 1.6 percent of total production. Quarries with an annual production of 816,326 Mg (900,000 tons) and over, on the other hand, accounted for 31 percent of production, but represented only 3.2 percent of the number of quarries.

Rock mined in these quarries is reduced to stone and graded into products in a stone-crushing plant. Plant capacities may range from less than a hundred to several thousand megagrams (tons) per hour. According to unpublished data for 1973 from the Bureau of Mines, 1785 quarries were reportedly serviced by stationary plants, 1533 by portable plants, and 112 by both.[2] A total of 781 quarries reported having no stone-crushing plants, leaving about 600 quarries unaccounted for.

4.1.1 Rock Types and Distribution

Major rock types processed by the industry include limestone and dolomite, which accounted for 73.2 percent of the total tonnage in 1973 and have the widest and most important applications; granite (11.4 percent); trap rock (7.9 percent); and sandstone, quartz, and quartzite (2.9

percent). Rock types including calcareous marl, marble, shell, slate and miscellaneous others accounted for only 4.6 percent. Nomenclature used by the industry varies considerably and in many cases does not reflect actual geological definitions.

Limestone and dolomite are sedimentary rocks formed by the deposition of animal and plant remains. In its pure state, limestone consists of crystalline or granular calcium carbonate (calcite); dolomite is calcium-magnesium carbonate. They are often found together in the same rock deposit. Depending on the proportions of the constituents, rock may be classified as limestone, dolomitic limestone, lime dolomite, or dolomite. Deposits are common and are distributed throughout most parts of the country. The major ones, however, are in the Central, Middle Atlantic, and South Atlantic regions, which contributed more than 93 percent of the total production in 1973.

The industry regards any light-colored, coarse-grained igneous rock as "granite." It is composed chiefly of quartz (SiO_2), feldspar, and, usually, mica. Deposits are found in the South Atlantic, Northeastern, North Central, and Western regions of the country. The South Atlantic region accounted for more than 77 percent of the total tonnage of granite produced in 1973.

Trap rock is any dark colored, fine-grained igneous rock composed of the ferro-magnesian minerals and basic feldspars and containing little or no quartz. Common varieties include basalts, diabases, and gabbros. Deposits are mostly found in the New England, Middle Atlantic, and Pacific regions, which combined accounted for 76 percent of all trap rock produced in 1973.

Sandstones and quartzitic rocks are scattered throughout the country. Sandstones are sedimentary rocks composed predominantly of cemented quartz grains. The cementing material may be calcium carbonate, iron oxide, or clay. Quartzites are siliceous cemented sandstones. All regions accounted for some production, with the Pacific, West South Central, and Middle Atlantic States combining for 60 percent of the total.

4.1.2 Applications

Crushed and broken stone has many and diverse uses both in its natural and processed state. The construction industry consumes about 86 percent of the total output. This breaks down to the following applications: dense graded road base stone, 24.4 percent of the total; concrete aggregate, 14.5 percent; unspecified construction aggregate and roadstone, 12.4 percent; cement manufacture, 10.9 percent; bituminous aggregate, 9.7 percent; surface treatment aggregate, 5.4 percent; and macadam aggregate, 3.3 percent.

These materials are also used in lime manufacture, 3.6 percent; agriculture, 3.2 percent; metallurgical flux, 2.7 percent; riprap and jetty stone, 2.6 percent, and railroad ballast, 1.7 percent. Remaining miscellaneous uses account for only about 5.6 percent of total production.

4.1.3 Demand for Crushed Stone

The long-term rate of growth (1963 through 1972) in the crushed stone industry has been at an annual rate of 3.3 percent. This will probably change over the remainder of the decade and through 1985 partly because the rate of construction expenditure is expected to decline from 2.1 percent to no more than 2.0 percent from 1972 to 1980 and also because the industry has reached stability with respect to product substitution. Thus, anticipated crushed-stone consumption should grow at about 3 percent per year, compounded from 1974 to 1985 on a tonnage basis.[3] The use of both limestone and granite is expected to increase in regard to their current proportion of total crushed-stone consumption. The use of these minerals is expected to grow at slightly faster rates than average. Little or no growth is anticipated in the consumption of trap rock or sandstone, and the use of miscellaneous stone types should continue to decrease in total tonnage.

4.1.4 Distribution

Crushed stone is distributed directly from the quarry to the user with no intermediary involved. It is readily available in most metropolitan areas because transportation and distribution are predominantly by truck. Inventories are held almost entirely at the quarry location because double handling would be prohibitively expensive, and customers maintain only sufficient inventory to insure uniform production rates over a predetermined time. Crushed-stone production and shipments are seasonal in many northern regions. Northern producers will typically operate their plants for 9 months a year and stockpile sufficient stone to cover a greatly reduced demand during the winter.

4.1.5 Plant and Firm Economics

Process Economics--

Two main types of plants are used, stationary and portable. The latter is merely a standard stationary plant mounted on a rubber-tired chassis, but it sometimes has an advantage over the stationary model. The portable plant is more useful to:

- highway contractors who supply their own construction materials at or close to the site,
- independent operators who move their equipment from quarry to quarry and prepare sufficient material to supply a rural county or township for a certain period,
- local public authorities.

More often than not, cost differentials between portable and stationary plants are dwarfed by the differentials between stone types processed.

The free on board (FOB) value of hard crushed stones, granite, trap rock, sandstone, and quartzite, for example, is higher than for soft stones such as limestone, dolomite, and marl. The higher costs of quarrying and crushing explain, in part, the FOB value differential.

Firm Characteristics--

The Bureau of the Census does not compile statistics on patterns of ownership in the mining industries, as it does in the manufacturing industries. It is difficult, therefore, to characterize the crushed-stone industry precisely in regard to the types of firms involved. It is possible, however, to make certain generalizations based on industry contacts and the past experience of an EPA consultant.[3]

The crushed-stone industry consists of a large number of small, locally owned firms which account for a minor proportion of national production, and a small number of larger firms which are regionally or nationally diversified and account for a large percentage of overall production. The relationships of quarries by size, as shown in Table 4-1, provide a reasonable description of the relative distribution of firms in the industry.

Patterns of firm ownership are similar to those in other sectors of the construction-oriented basic materials industry. Types range from small, local companies in which the plant manager and the owner are often the same person to plants owned by diversified major firms. Many of these larger firms also operate captive quarries to supply their other manufacturing businesses such as steel mills, lime plants, and cement mills. Between the two extremes are firms that are less diversified in terms of geography and business, yet which can compete effectively with the larger firms on a regional basis.

Financial Resources--

Table 4-2 depicts the financial profile of a typical crushed-stone plant. The following points from this table are worth noting:

- The industry operates on an average rate of profitability for all U.S. firms. Net profit margins are 7 percent; returns on shareholders' equity 11 percent.
- The industry is capital intensive and moderately leveraged. Debt represents 1/3 of total capitalization.
- Depreciation and depletion represent major sources of funds for capital expansion.
- A major portion of the industry's assets is tied-up in working capital, primarily inventories and accounts receivable.

It should be stressed that Table 4-2 is a typical statement, a synthesis of information from the Department of

Table 4-2. TYPICAL CRUSHED-STONE PLANT FINANCIAL STATEMENTS[3]

(Index: Revenues = 100)

BALANCE SHEET

Current assets	60	Current liabilities	30
Fixed assets		Long-term debt	32
Land	8	Equity	64
Plant and equipment	110		
Accumulated depreciation	(55)		
Miscellaneous assets	3		
Total assets	126	Total liabilities	126

Income statement		Source and application of funds	
Revenues	100	Sources	
Production costs		Net income	7
Direct labor	(19)	Depreciation	10
Materials	(20)	Depletion	2
Repair and maintenance	(19)	Increase in long-term debt	3
Gross margin	42		22
Fixed costs		Application	
SG&A	(14)	Capital expenditures	16
Depreciation	(10)	Land purchase	2
Depletion	(2)	Increase in working capital	3
Interest	(4)	Dividends	1
Profit before taxes	12		22
Taxes	(5)		
Net profit	7		

Commerce and the Bureau of Mines together with that obtained during an earlier study.[3] These figures may vary significantly for individual plants according to such parameters as the following:

- Plant size. Larger plants enjoy economies of scale that enable them to increase labor utilization. Labor as a percentage of revenues may be reduced by 30-40 percent (to 12-15% of revenues) in modern plants in the 909-Mg/h (1000-tons/h) category.
- Plant age. Newer plants have proportionately larger depreciation charges, offset by smaller expenses for repairs and maintenance. With higher investment bases, newer plants have lower returns on net assets and shareholders' equity.
- Plant location. Costs differ between plants in different locations based on the supply and demand relationships for labor and materials. In the Northeast, for example, the cost of materials (e.g., fuel) and labor is higher, relative to other costs, than in the South. In addition, the market environment in which a plant operates will determine the attainable revenue for each plant. Plants that are favorably located relative to their competition will realize greater profit margins.

4.1.6 Current Prices

In April 1977, quotations in Engineering News Record for carload lots of 3.8-cm (1-1/2-in.) crushed stone ranged from $8.10 per Mg ($7.35 per ton) in Minneapolis to $1.98 ($1.80) in St. Louis. These prices are based on an FOB city basis and are summarized in Table 4-3. The average price of 3.8-cm (1-1/2-in.) stone for the 18 cities shown in the

Table 4-3. CRUSHED-STONE PRICES FOB CITY

Region/city	Price range as of April 1977, $ per Mg[a]	
	3.8-cm stone (1-1/2-in. stone)	1.9-cm stone (3/4-in. stone)
NEW ENGLAND		
Boston	3.91	4.13
MIDDLE ATLANTIC		
New York	6.33	6.33
Philadelphia	4.57	4.57
Pittsburgh	7.81	8.03
EAST NORTH CENTRAL		
Chicago	2.48	2.92
Cincinnati	3.19	3.19
Cleveland	5.59	5.59
Detroit	3.41	3.52
WEST NORTH CENTRAL		
Kansas City	3.80	3.80
Minneapolis	8.09	8.09
St. Louis	1.98	1.98
SOUTH ATLANTIC		
Atlanta	4.68	5.01
Baltimore	3.47	3.58
EAST SOUTH CENTRAL		
Birmingham	2.09	2.09
WEST SOUTH CENTRAL		
Dallas	5.73	6.01
PACIFIC		
Los Angeles	4.97	4.97
San Francisco	7.81	6.82
Seattle	7.43	7.43

[a] $ per ton = 0.91·$ per Mg.

table is \$4.85 per Mg (\$4.41 per ton). For 1.9-cm (3/4-in.) crushed stone, the average is \$4.89 per Mg (\$4.45 per ton).

These price quotations include transportation costs that might range from \$0.55 to \$1.65 per Mg (\$0.50 to \$1.50 per ton) from quarry to city.

4.2 COST OF CONTROLLING PROCESS SOURCES

Control methods generally applied to process-generated emissions include dry collection, wet dust suppression, and a combination of the two. Dry collection involves hooding or enclosing dust-producing points and exhausting emissions to a collection device. Wet dust suppression consists of introducing moisture into the material flow to prevent fine particulate matter from becoming airborne. Combination systems apply both methods at different stages throughout the process.

4.2.1 Cost Estimation

Capital investment and annual costs for retrofitting existing plants with each of the control systems are presented under separate headings. Table 4-4 lists cost elements of total capital investment. Investment for a particular case can be estimated by adding up costs of applicable elements. Annual costs were estimated by adding up items listed in Table 4-5. For comprehensive presentation,

Table 4-4. ESTIMATION OF CAPITAL INVESTMENT FOR CONTROL DEVICES

Component	Direct costs	
	Material	Labor
Equipment		
Ductwork		
Stack		
Instrumentation		
Electrical		
Foundations		
Structural		
Sitework		
Painting		
Piping		
Total direct costs		

Component	Indirect costs	
	Measure of costs	Costs
Engineering	10% material and labor	
Contractor's fee	15% material and labor	
Shakedown	5% material and labor	
Spares	1% material	
Freight	3% material	
Taxes	3% material	
Total indirect costs		
Contingencies - 10% of direct and indirect		
Total fixed capital		
Working capital		
Total investment		

Table 4-5. CALCULATION OF ANNUALIZED COSTS OF AIR POLLUTION CONTROL SYSTEMS

Cost component	Method of calculation
Direct operating costs	
Utilities	
Water	Amount used per year x \$0.0625/m^3 (\$0.25/1000 gal)
Electricity	Amount used per year x 0.04/kWh
Operating labor	
Direct	Number of man-hours per x \$5.00 to \$6.50/h
Supervision	15% of direct labor
Maintenance and supplies	
Labor and material	3 to 10% of fixed capital investment
Supplies	15% of labor and material
Fixed costs or indirect charges	
Overhead	
Plant	50% of rated operating labor plus 50% of maintenance and supplies or 3% of fixed capital investment
Payroll	20% of operating labor
Capital charges	
Capital recovery	13.2% of fixed capital investment[a]
Insurance and taxes	2% of fixed capital investment

[a] Based on a 15-year loan at 10 percent interest.

several cost items are often lumped together. For example, lump sum labor cost may include costs for direct labor, supervision, payroll overhead, and plant overhead. Fixed charges account for depreciation, interest, administrative overheads, property taxes, and insurance. Depreciation and interest are computed by means of a capital recovery factor (CRF), the value of which depends on the operating life of the control device and on the interest rate. Unless stated otherwise, an operating life of 15 years and an annual interest rate of 10 percent are assumed. Three sizes of plants were considered: a 182-Mg/h (200-tons/h) portable unit, and a 273-Mg/h and a 545-Mg/h (300- and 600-tons/h) stationary plant.

The cost per unit of pollutant removed, i.e., cost-effectiveness, is computed for the dry collection system. Because estimates of emissions from plants controlled with wet dust-suppression systems or combination control systems are not available, cost-effectiveness cannot be computed.

4.2.2 Dry Collection Systems

The most commonly used dust collection device in the crushed-stone industry is the fabric filter, or baghouse. Capital investment of fabric filter systems for the three model plant sizes were obtained from cost data in Reference 4. The costs are based on the following general specifications:

- Polypropylene felt bags are used;
- Fabric filter housings are constructed of carbon steel;
- Collection efficiency is 99.8 percent;
- The collector operates at negative pressure with the fan located at the outlet side of the filter;
- Bags are cleaned by air pulse jet.

Based on generalized exhaust gas volume data, Figure 4-1 shows exhaust gas volumes of fabric filter systems in plants of various sizes. Tables 4-6 and 4-7 present capital investment and annual costs, respectively, of the three fabric filter systems. Costs of necessary hooding and enclosures and ductwork are included. The 182-Mg/h and 273-Mg/h (200- and 300-tons/h) plants have two baghouses, and the 545-Mg/h (600-tons/h) plant has three. Figure 4-2 shows the variation of cost effectiveness with plant capacity.

4.2.3 Wet Dust-Suppression System

In a wet dust-suppression system, dust emissions are controlled by applying moisture to the crushed material at critical dust-producing points in the process flow as shown in Figure 3-1. This causes dust particles to adhere to large stone surfaces or to form agglomerates too heavy to become or to remain airborne.

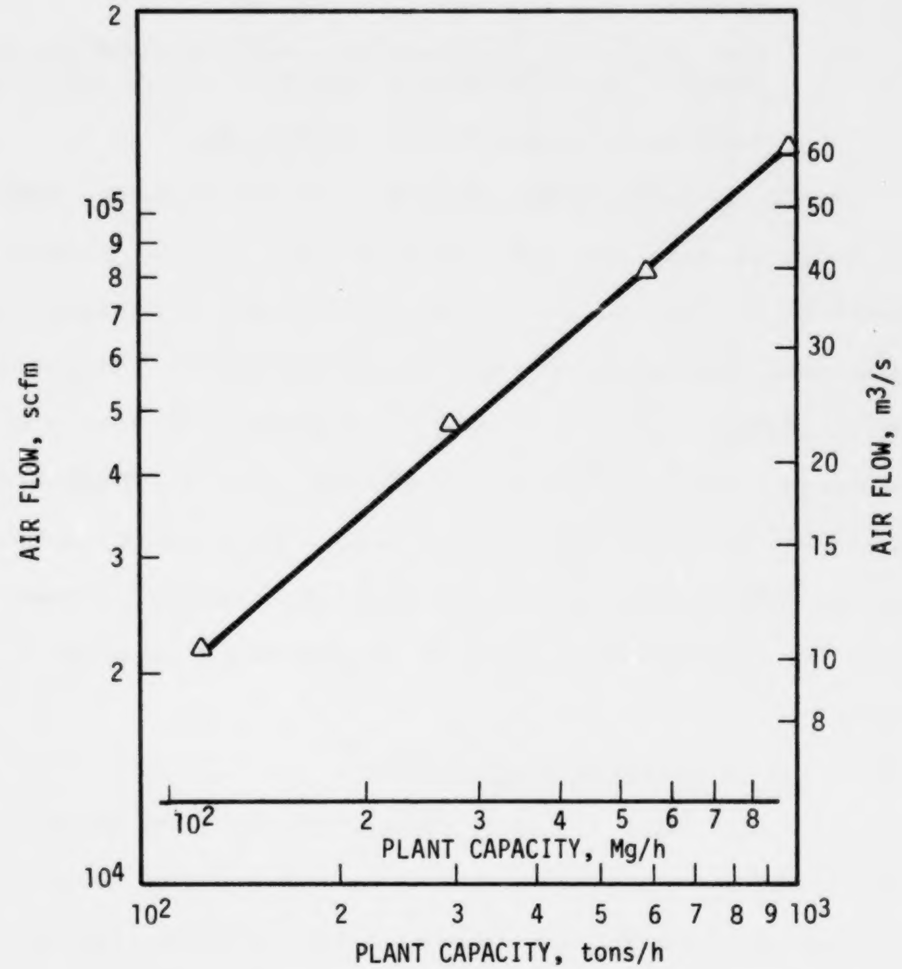

Figure 4-1. Exhaust gas volumes at various plant capacities[3].

Table 4-6. CAPITAL INVESTMENT OF FABRIC FILTER SYSTEMS

Process parameter	182 Mg/h (200 tons/h)	Plant size 273 Mg/h (300 tons/h)	545 Mg/h (600 tons/h)
Exhaust gas rate,[a] m^3/s (acfm)	15.5 (33,000)	26.7 (48,000)	38.7 (82,000)
Filter area at 6.5 A/C, m^2 (ft^2)	470 (5,100)	690 (7,400)	1,180 (12,600)
No. of filters (baghouses)	2	2	3
Fixed capital investment	\$144,800[b]	\$202,000[b]	\$339,800[b]

[a] See Figure 4-1.

[b] From Reference 4. Data in Reference 4 are based on data in Reference 5.

Table 4-7. ANNUAL COSTS OF FABRIC FILTER SYSTEMS[a]

(2200 operating hours per year @ 75 percent of rated capacity)

(Costs for December 1976)

Items	182 Mg/h (200 tons/h)	273 Mg/h (300 tons/h)	545 Mg/h (600 tons/h)
Electric power (103, 144, 260) (hp) (0.75 kW/hp) (1650 h/yr) ($0.04/kWh)	$10,450[b]	$7,130	$12,870
Maintenance labor (4, 6, 10 h/wk) (h/wk)($5.50/h)(52 wk/yr)	1,140	1,720	2,860
Maintenance material	3,520	4,720	7,920
Operation labor (1,2,3 h/wk) (h/wk)($5.50/h)(52 wk/yr)	220	560	840
Supplies[c]			
Bags (416,605,1034) ($4.31/$m^2$) ($m^2$)/2	1,020	1,480	2,520
(Bags)(0.1 man-hour/bag)($5.50/h)	110	170	300
Payroll overhead (35% of labor)	500	800	1,300
Indirects (40% of maintenance and supplies)	2,320	3,230	5,440
Insurance and local taxes (2% of fixed capital)	2,900	4,040	6,800
Capital recovery (13.2% of fixed capital)	18,820	26,260	44,170
Total Costs	$ 41,000	$ 50,110	$ 85,020
Annual tonnage, Mg	299,300	449,000	898,000
(ton)	(330,000)	(495,000)	(999,000)
Unit cost, ¢/Mg	13.7	11.2	9.5
(¢/ton)	(12.5)	(10.1)	(8.5)
Cost-effectiveness[d]			
¢/kg pollutant removed	2.5	2.0	1.7
(¢/lb pollutant removed)	(1.2)	(0.9)	(0.7)

[a] From Reference 4.

[b] Diesel power assumed for 200-ton portable plant (equivalent cost 8.2¢/kWh).

[c] Based on 2-year bag life and filter are as in Table 4-6.

[d] Based on uncontrolled emissions of 5.5 kg/Mg (11.0 lb/ton).

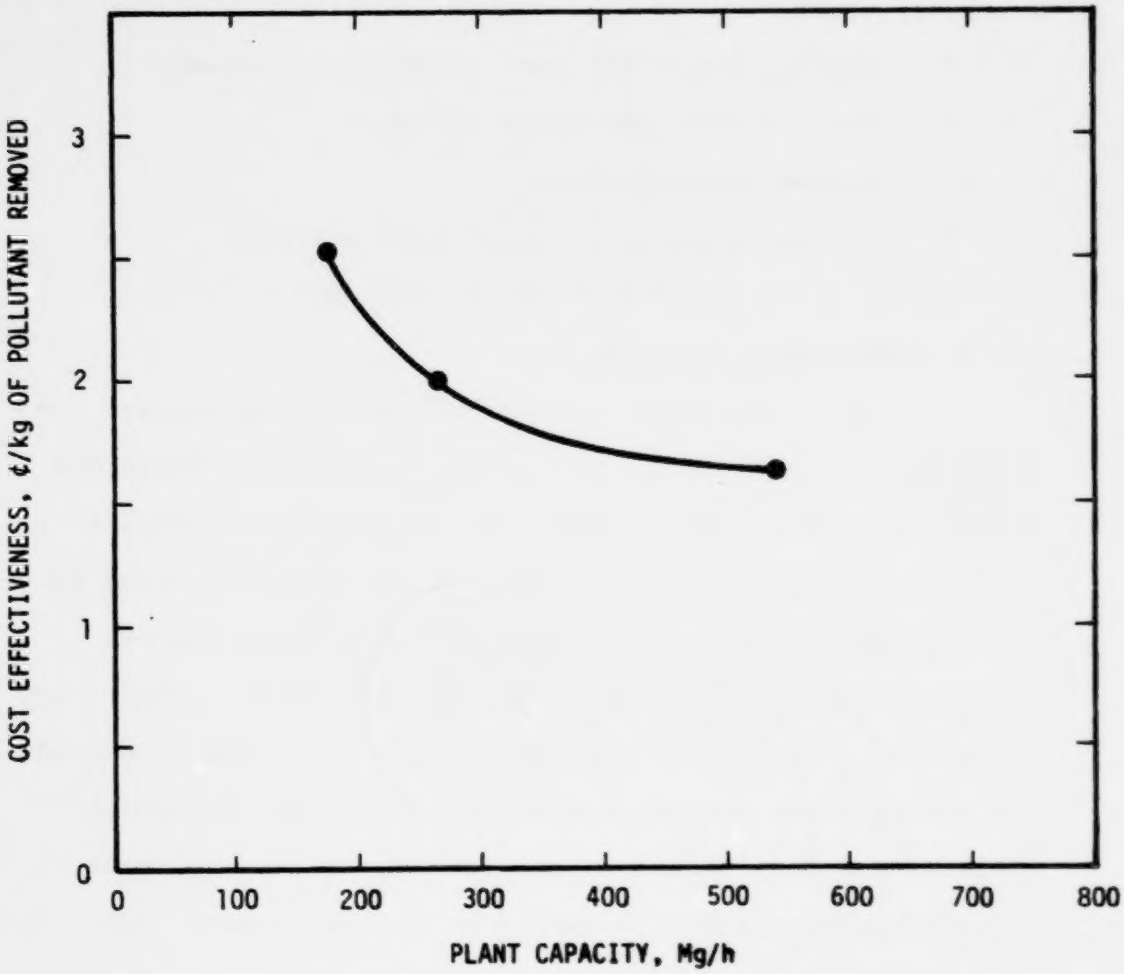

Figure 4-2. Cost-effectiveness of fabric filter (dry collection) systems.

Table 4-8 presents capital investment of wet dust-suppression systems. The systems include the following auxiliary items:

- Shelter house for pump metering mechanism,
- Water filter and flush system,
- System winterization,
- Automatic spray at truck dump station.

Annual costs are presented in Table 4-9.

4.2.4 Combination Systems

Wet dust-suppression and dry collection techniques are often used in combination to control particulate emissions from crushed-stone facilities. As illustrated in Figure 3-5, wet dust-suppression techniques are generally used to control emissions at the primary crushing stage and at subsequent screens, transfer points, and crusher feeds. Dry collection is generally used to control emissions at secondary and tertiary crusher discharges, where new dry stone surfaces and fine particles are formed. A large portion of the fine particulates is removed by dry collection, but subsequent dust-suppression applications become more effective with a minimum of added moisture. Depending on production requirements, dry collection may be the only method that can be used at the finishing screens.

Table 4-8. CAPITAL INVESTMENT OF WET DUST-SUPPRESSION SYSTEMS[a]

(Costs for December 1976)

Items	Plant size		
	182 Mg/h (200 tons/h)	273 Mg/h (300 tons/h)	454 Mg/h (600 tons/h)
Dust-suppression equipment	$10,050	$11,610	$15,060
Auxiliary equipment			
Water filter and flush	2,280	2,280	2,280
High pressure truck dump station	5,490	5,760	4,210
Shelter house	2,170	2,170	2,170
Equipment winterization	2,660	2,880	3,080
Auxiliary equipment total	$12,600	$13,090	$11,740
Total equipment cost	$22,650	$24,700	$26,800
Installation costs - direct			
Foundation and supports	860	860	860
Piping	17,500	18,240	19,970
Insulation	4,780	5,160	5,860
Painting	None	None	None
Electrical	13,160	13,190	13,730
Total direct installation costs	$36,300	$36,450	$40,420
Installation costs - indirect			
Engineering	1,900	2,030	2,140
Construction and field expense	1,390	1,500	1,710
Construction fees	360	360	360
Start-up	1,710	1,710	1,710
Performance	370	380	400
Contingencies	1,820	1,870	2,020
Total indirect installation costs	$ 7,550	$ 7,850	$ 8,340
Fixed capital investment	$66,500	$70,000	$75,560

[a] Cost data for the 182-Mg/h (200-tons/h) plant are estimated from data in Reference 5; data for the remaining two plants are from Reference 5.

Table 4-9. ANNUAL COSTS OF WET DUST-SUPPRESSION SYSTEMS[a]

(2200 operating hours per year @ 75 percent of rated capacity)

(Costs for December 1976)

Cost item	Unit cost or basis	Plant size		
		182 Mg/h (200 tons/h)	273 Mg/h (300 tons/h)	545 Mg/h (600 tons/h)
Operating labor[b]				
Operator	$5.50/h	$360	$360	$360
Supervisor	$7.00/h	120	120	120
Subtotal		$480	$480	$480
Maintenance				
Labor	$6.00/h	$240	$290	$430
Materials		670	1,000	1,500
Subtotal		$910	$1,290	$1,930
Replacement parts		$460	$ 460	$ 460
Utilities				
Electricity	$0.04/kWh	$ 75	$100	$250
Water[c]	$0.066/m^3	60	90	180
Subtotal		$135	$190	$430
Wetting agent[d]	$880/m^{3}[c]	$800	$1,200	$2,410
Total direct costs		$2,785	$3,620	$5,710
Fixed charges				
Overhead	20% of labor +50% of labor & maintenance	790	980	1,300
Insurance and local taxes	2% of fixed capital	$1,330	$1,400	$1,510
Capital recovery	13.2% of fixed capital	8,640	9,100	9,820
Total fixed charges		$10,760	$11,480	$12,630
Total annualized cost		$13,545	$15,100	$18,340
Annual output, Mg (ton)		299,300 (330,000)	449,000 (495,000)	898,000 (990,000)
Unit cost, ¢/Mg (¢/ton)		4.5 (4.1)	3.3 (3.0)	2.0 (1.8)

[a] From Reference 4.

[b] System operation is automatic. The only labor required on a daily basis is that needed to start the system.

[c] Computed on basis that wetting agent treatment is required only 40 percent of operation time becuase of initial moisture content of the material and prevailing weather conditions.

[d] Assumes high volume purchase of wetting agent. i.e., greater than 2.27 m^3 (600 gal) per order.

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Tables 4-10 and 4-11 present capital investment and annual costs, respectively, of the model combination control systems.

4.3 COST OF CONTROLLING FUGITIVE DUST SOURCES

Table 2-1 categorizes all emission sources associated with crushed-stone production as either process or fugitive. Fugitive dust sources include blasting, loading and hauling, open conveyors, and storage piles. Emissions are caused by load-in, load-out, and wind. This section presents the cost of controlling these fugitive dust sources. Because estimates of emissions from fugitive dust sources are not available, cost-effectiveness cannot be computed.

4.3.1 Blasting

No method is known for effectively controlling particulate emissions from blasting operations. As discussed in Section 3.1.2, the impact of blasting may be reduced by employing good blasting practices.

4.3.2 Loading and Hauling

As discussed in Chapter 2, no effective method is known for suppressing or capturing emissions from loading. Watering the material in the trucks after they have been loaded will reduce emissions from the trucks during hauling. Several methods available for reducing or controlling

Table 4-10. CAPITAL INVESTMENT OF COMBINATION SYSTEMS

(Fabric filter and wet dust suppression)

	Plant size		
	182 Mg/h (200 tons/h)	273 Mg/h (300 tons/h)	545 Mg/h (600 tons/h)
Process parameter			
Exhaust gas rate for fabric filter system, m^3/s (acfm)	5.2[a] (11,000)	7.8[b] (16,500)	11.8[b] (25,000)
Filter area at 6.5 A/C, m^2 (ft^2)	160 1,700)	240 2,540)	360 (3,850)
No. of filters (baghouses)	1	1	1
Capital investment			
Fabric filter	72,000[c]	92,000[c]	120,000[c]
Wet dust-suppression system	59,000[d]	63,000[d]	68,000[d]
Total fixed capital investment	131,000	151,000	188,000

[a] Estimate based on data in Reference 6.

[b] Reference 6.

[c] Based on data in Reference 5.

[d] Based on data in Reference 5; these costs are estimated to be 90 percent of the costs of wet dust-suppression systems alone.

Table 4-11. ANNUAL COSTS OF COMBINATION SYSTEMS

(Fabric filter and wet dust suppression)

(2200 operating hours per year @ 75 percent of rated capacity)

	Plant size		
	182 Mg/h (200 tons/h)	273 Mg/h (300 tons/h)	545 Mg/h (600 tons/h)
Direct costs for dust-suppression system	$ 2,900[a]	$ 3,750[a]	$ 5,810[a]
Overhead for dust-suppression system	790[a]	980[a]	1,300[a]
Subtotal	3,690	4,730	7,110
Direct costs for fabric filter system			
Electric power (38, 51, 86) (hp)(.75 kW/hp)(1650 h/yr) ($.04/kWh)	3,860[b]	3,520	4,260
Maintenance labor (4,4,4 h/wk) (h/wk) ($5.50/h) (52 wk/yr)	1,140	1,140	1,140
Maintenance material	1,200	1,500	2,000
Operation labor (1,1,1 h/wk) . (h/wk) ($5.50/h (52 wk/yr)	220	220	220
Supplies[c]			
Bags (139, 208, 315) ($4.31 m^2)(m^2/2)	340	510	770
(Bags)(0.1 man-hours)($5.50/h)	40	60	90
Overhead for fabric filter system			
Payroll overhead (35% of labor)	480	480	480
Indirects (40% of maintenance and supplies)	1,090	1,280	1,600
Subtotal	8,370	8,710	10,560
Insurance and local taxes (2% of fixed capital)	2,620	3,100	3,760
Capital recovery (13.2% of fixed capital)	17,030	20,150	24,440
Total annual costs	$31,710	$36,690	$45,870
Annual tonnage, Mg	299,200	449,000	898,000
(ton)	(330,000)	(495,000)	(990,000)
Unit cost, ¢/Mg	10.6	8.1	5.1
(¢/ton)	(9.6)	(7.4)	(4.6)

[a] From Table 4-8.

[b] Diesel power assumed for 182-Mg/h (200-tons/h) portable plant (equivalent cost 8.2¢/kWh).

[c] Based on 2-year bag life and filter areas in Table 4-10.

emissions from trucks traveling on unpaved roads include watering, oiling, paving, and limiting vehicle weight and reducing vehicle speed. Sweeping or vacuuming reduces emissions on paved roads.

Published truck speed data are not available, but the industry estimates that the speed ranges from 10 to 20 mph.[7] If this speed were reduced from an average of 15 to an average of 10 mph, this would produce an estimated emission reduction of 65 percent.[8] More vehicles would be required to maintain production, but particulate emission reduction would still remain at 65 percent because there would be no increase in mileage. The estimated costs of this emission reduction method for the model plants are shown in Table 4-12. The costs are based on an estimated requirement of one additional 31.8-Mg (35-ton) truck for the 182-Mg/h (200-tons/h) and 273-Mg/h (300-tons/h) plants and two trucks for the 545-Mg/h (600-tons/h) plant. Table 4-12a presents unit cost data for controlling fugitive dust emissions from plant roads.

Table 4-12 also presents capital investment and annual costs of paving, sweeping or vacuuming paved roads, oiling, and watering. These costs depend on the extent of plant roads, which usually do not vary significantly with plant capacity. Consequently, the control cost per ton of crushed

Table 4-12. CAPITAL INVESTMENT AND ANNUAL COSTS FOR CONTROLLING FUGITIVE DUST EMISSIONS FROM CRUSHED-STONE PLANT ROADS

Item	Plant size		
	182 Mg/h (200 tons/h)	283 Mg/h (200 tons/h)	545 Mg/h (600 tons/h)
Capital investment, $			
Paving	28,000	28,000	28,000
Vacuuming	22,000	22,000	22,000
Oiling (annual costs)	30,000	30,000	30,000
Watering	14,000	14,000	14,000
Speed reduction[a]	150,000	150,000	300,000
Annual Costs, $			
Paving	8,400	8,400	8,400
Vacuuming	11,400	11,400	11,400
Oiling	30,000	30,000	30,000
Watering	31,300	31,300	31,300
Speed reduction[a]	87,500	87,500	175,000
Annual costs, ¢/Mg[b]			
Paving	2.8	1.9	0.9
Vacuuming	3.9	2.5	1.3
Oiling	10.0	6.6	3.3
Watering	10.5	6.9	3.5
Speed reduction[a]	32.2	19.5	19.5

[a] Based on two 31.8-Mg (35-ton) trucks for the 182-Mg/h (200-tons/h) and 273-Mg/h (300-tons/h) plants and two trucks for the 545-Mg/h (600-tons/h) plant.

[b] ¢/ton = 0.91 x ¢/Mg.

Table 4-12a. UNIT COSTS FOR CONTROLLING FUGITIVE DUST EMISSIONS FROM CRUSHED-STONE PLANT ROADS

Control measure	Capital cost		Annual cost, $/yr[a]	Comment
	unit	$/unit		
Paving	1.7 km, 3.65 m wide (1 mile, 12 ft wide)	28,000[b]	8,400	Repave every 5 years
Vacuuming	one sweeper	22,000[b]	11,400[c]	Vacuuming twice a week
Oiling	1.7 kg, 365 m wide (1 mile, 12 ft wide)	5,000[b]	30,000	Reoil every month
Watering	Truck equipped with a 1.1-kl (3000-gal) tank	12,000 to 16,000[d]	31,300[e]	Watering the roads four to five times a day
Speed reduction[f]	One 31.8-Mg (35-ton) truck	150,000	87,500[g]	Estimated truck life of 5 years

[a] The cost of capital (interest) assumed at 10 percent.

[b] From Reference 9.

[c] Assumed vacuum life of 5 years; maintenance at 3 percent of capital cost; labor at 8 hours per week, $9.25 per hour including overhead.

[d] From References 10 and 11.

[e] See Table 4-13.

[f] Estimated.

[g] Includes wages of truck driver at $12 per hour, including overhead.

stone will be higher than the average for smaller plants. The length of unpaved roads in a typical crushed-stone plant is estimated to be 0.63 km (1 mile). Table 4-13 presents a breakdown of the annual cost of watering. The costs are based on a watering frequency of four to five times a day.

4.3.3 Conveyors

Emissions from conveyor transfer points are considered to be process emissions, whereas those due to wind are regarded as fugitive. The latter can be controlled or suppressed by installing covers over the conveyors or water sprayers along their length. If the material being conveyed is sprayed at the conveyor inlet (which may be a crusher/ screen outlet or transfer point), the suppression effect is usually carried over; hence, installation of additional sprayers may only marginally increase the suppression efficiency. For this reason, costs of installing sprayers are not estimated here. Costs of retrofitting covers on existing conveyors may range from \$35 to \$70 per foot of conveyor length, depending on the amount of work required and the type of covering.[12,13] The lower figure applies to a "weather-tight" system, which protects the conveyed material from direct winds and precipitation. A "dust-tight" system, which is usually vented to a bag filter, costs twice as much. Total conveyor lengths for crushed-stone plants

Table 4-13. ANNUAL COST OF WATERING[a] CRUSHED-STONE PLANT ROADWAYS

Cost item	Quantity	Unit cost	Cost/year
Operating costs			
Water	136 m^3/day (36,000 gal/day)	\$0.063/m^3 (\$0.25/1000 gal)	\$ 2,300
Fuel	9.5 liters/day (2.5 gal/day)	\$0.13/liter (\$0.50/gal)	300
Labor	2,000 h	12.00[b]/man-hour	24,000
Maintenance	5% of initial tank-truck cost[c]		700
Fixed charges			
Capital recovery	26.4% of initial tank-truck cost[d]		3,700
Insurance and taxes	2% of initial tank-truck cost[c]		300
		Total annual cost	\$31,300
Cost per ton for a 182-Mg/h (200-tons/h) plant[e]			10.5¢/Mg
Cost per ton for a 273-Mg/h (300-tons/h) plant[e]			6.9¢/Mg
Cost per ton for a 545-Mg/h (600-tons/h) plant[e]			3.5¢/Mg

[a] Based on annual production rates in Table 4-7.

[b] Includes supervision @ 15 percent, payroll overhead @ 20 percent, and plant overhead @ 50 percent of direct labor.

[c] Engineering estimate.

[d] Based on 5-year truck life and 10 percent interest.

[e] ¢/ton = 0.91 x ¢/Mg.

vary significantly, ranging from a few hundred to a few thousand feet. Because maintenance costs of conveyor covers are minimal, the annual cost will depend mainly on the remaining plant life and the cost of capital (interest).

4.3.4 Storage Piles

Fugitive emissions from storage piles are due to load-in, wind erosion, and load-out.

Materials at crushed-stone plants are usually taken to storage piles via a conveyor system. Emissions result mainly from the free fall of material onto the pile. As discussed in Chapter 3, control measures include wet dust suppression, telescopic chutes, stone ladders, and movable stacking conveyors. Enclosures or silos are very good for controlling load-in and windblown emissions; however, they are not considered economically practical control measures for crushed-stone plants. Table 4-14 presents capital investment costs of stone ladders, telescoping chutes, movable stackers, and enclosures. Because this equipment requires very little maintenance, the annual cost will depend mainly on the remaining plant life and the cost of capital (interest).

Spraying storage piles with water effectively reduces fugitive emissions from wind erosion, and the addition of dust-suppressant chemicals to the spray increases control

Table 4-14. CAPITAL INVESTMENT FOR REDUCING FUGITIVE DUST EMISSIONS FROM STORAGE PILES

Control measure	Fixed capital investment	
	Unit	$/unit
Stone ladder	9.1-m (30-ft) pile	20,000[a]
Telescoping chutes	Chute	26,000-42,000[b]
Movable stacker	0.907 Mg (ton) per hour throughput	700[a]
Enclosures	0.76 m^3 (yd^3)	80-200[b]

[a] Reference 14.

[b] Reference 15.

efficiency. The truck that waters plant roads can be equipped with a hose for spraying storage piles. Alternatively, an elevated sprinkler system may be used to spray the stock piles. The cost of elevated sprinkler systems ranges from a few thousand dollars to $20,000, depending on the plant. If the sprinkler pump could be accommodated in an existing pump house, for example, this would save the cost of a new pump house.[16] Costs of spraying storage piles with a wetting agent are estimated to range from $0.01 to $0.06[17,18] per Mg ($0.05/ton) of product, depending on the type of chemical used, the number of storage piles, and the frequency of spraying. The latter depends on climate and operational activities around the pile.

Crushed stone is usually loaded into trucks by front-end loaders. As discussed in Section 4.3.2, there is as yet no acceptable way of suppressing or capturing the load-out emissions. Watering the material in trucks after they have been loaded will reduce emissions during hauling.

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5.0 ENVIRONMENTAL IMPACT OF APPLYING CONTROL TECHNOLOGY

This section presents an assessment of the incremental impact to the environment associated with the application of the emission reduction systems described in Chapter 3. Both beneficial and adverse impacts are assessed on air, water, solid waste, energy, and noise that may be directly or indirectly attributed to the operation of these emissions control systems.

5.1 IMPACT ON AIR

Ideally, this section should present a comparative assessment of impacts on air emissions associated with the application of the alternative emission reduction systems (described in Chapter 3) for the control of particulate emissions from both process and fugitive dust sources. Because emissions from fugitive dust sources are typically large in area and are discharged directly to the atmosphere in an unconstrained manner rather than through a stack, such a quantitative measurement of these emissions would be difficult, if not impossible. Consequently, few data are available that permit the calculation of the emission reduction achievable by the application of alternative control measures. Similarly, because of the nature of wet dust suppression systems, no data are available that permit a quantitative comparison of the control capabilities of wet dust suppression versus dry collection systems on process sources. As a result, the following discussion on air impact is necessarily limited to the application of dry collection systems on crushed and broken stone process facilities.

Table 5-1 presents estimates of the emission reduction achievable by the application of dry controls on three model plants reflecting typical production capacities of 182, 273, and 545 Mg/h (200, 300, and 600 tons/h). Estimates of uncontrolled emissions presented are based on the uncontrolled emission factor for process sources alone (reported in Subsection 2.1), which is 5.5 kg/Mg of capacity (11 lb/ton). As indicated by the performance data presented in Section 3, the use of fabric filters to collect particulate emissions at stone plants can easily achieve an outlet concentration of 0.034 g/dry m^3 (0.015 gr/dscf). If adequate hooding and ventilation are also applied, essentially complete capture is assured. The emission estimates with dry controls were developed by assuming a 99 percent capture efficiency and applying the fabric filter outlet concentration value to the total ventilation requirements estimated for each model plant. As shown in Table 5-1, uncontrolled emissions from the 182, 273, and 545 Mg/h plants were calculated to be 998, 1497, and 2994 kg/h, respectively. The application of dry controls was estimated to reduce emissions to about 12, 18 and 35 kg/h, which corresponds to an overall emission reduction of about 98.8 percent.

TABLE 5-1. ACHIEVABLE EMISSION REDUCTION USING DRY COLLECTION SYSTEM

Plant size, Mg/h (tons/h)	Ventilation size, m^3/s (scfm)	Emissions		Emission reduction, %
		Uncontrolled, kg/h (lb/h)	Dry collection, kg/h (lb/h)	
182 (200)	15.3 (32,500)	998 (2,200)	11.9 (26.2)	98.8
273 (300)	22.3 (47,300)	1,497 (3,300)	17.7 (39.1)	98.8
545 (600)	38.0 (80,800)	2,994 (6,600)	34.7 (76.4)	98.8

5.2 IMPACT ON WATER POLLUTION

Dry collection control techniques generate no water effluent. When wet dust-suppression techniques can be used, the water is absorbed by the material processed so that wet dust-suppression systems produce no water effluent either.[1] No data are available concerning the impact of dust-suppressants applied to roadways on water quality. Considering the amount of suppressants required, however, the use of suppressants should not cause any problem. Thus, the application of air pollution control technology to the crushed- and broken-stone industry has little impact on water quality.

5.3 IMPACT ON SOLID WASTE DISPOSAL

The method of disposition of quarry, plant, and dust collector waste materials depends somewhat upon state and local government and corporate policies. When fabric filter systems are used, about 1.2 Mg (1-1/3 tons) of solid waste are collected for every 227 Mg (250 tons) of rock processed.[2] Often, this material can be sold or used for a variety of purposes. Many plants sell the collected fines from trap-rock, granite, limestone, etc., as mineral filler for the manufacture of asphalt concrete. Many companies operate both quarries and asphalt-concrete plants. Depending on the chemical composition of the rock, some limestone quarries sell the collected fines as agstone. Limestone screenings and wastes are also an effective long-term neutralizing agent on acidic spoils from mining operations.[3] Such spoils generally continue to produce acidity as oxidation continues. The application of limestone wastes produces alkalinity on a decreasing scale for many years, after which a vegetative cover should be well established.

Collected fines are normally disposed of in an isolated location in the quarry if no market is available. A plant producing 545 Mg/h (600 tons/h) and using dry collection for control would generate about 22 Mg (24 tons) of waste over an 8-hour period, which is less than 0.5 percent of the plant throughput. Generally, the collected fines are discharged to a haul truck and transported to the quarry for disposal.[4] No subsequent air pollution problems should develop, provided the waste pile is controlled by one of the methods discussed in Chapter 3.

Thus, the solid waste generated by the application of dry collection methods in the crushed-stone industry can be dispersed of without any adverse impact on the environment.[5] When wet dust suppression is used, no solid-waste-disposal problem results over that produced by normal operation.

5.4 IMPACT ON ENERGY CONSUMPTION

Application of the alternative control techniques for crushed and broken stone production facilities will necessarily result in an increase in energy consumption over that required to operate a plant without air pollution controls. Table 5-2 presents estimates of the energy requirements for three typical plants, both with and without controls. The three model plants evaluated, which are identical to those used to determine the costs in Chapter 4 and the impacts on air in Section 5.1, include a portable plant with a capacity of 182 Mg/h (200 tons/h) and two stationary plants with production capacities of 273 and 545 Mg/h (300 and 600 tons/h). As in the previous analyses, the alternative control techniques evaluated include dry collection, wet dust suppression, and the combination of dry and wet controls.

As might be expected, the application of dry collection controls (fabric filters) results in the highest increase in energy usage of the three alternative control techniques evaluated. As indicated in Table 5-2, the energy required to operate a 545 Mg/h plant without controls is about 1038 kW (1392 hp). The application of dry controls at this plant would require 194 kW (260 hp) of additional energy to operate the fans, air compressors, and screw conveyors associated with its application. This represents a 19 percent increase in energy consumption over that required to operate the uncontrolled plant. At the 182 and 273 Mg/h plants, the application of dry controls would increase energy requirements by 16 and 17 percent respectively.

In contrast, the energy requirement associated with the application of wet dust suppression systems is negligible. For the 545 Mg/h plant, the application of wet dust suppression control would require only 3.8 kW (5 hp) of additional energy, or less than a 0.4 percent increase in energy consumption. For the two smaller model plants, the increase in energy consumption due

TABLE 5-2. ENERGY REQUIREMENTS FOR MODEL CRUSHED STONE PLANTS
[kilowatts (horsepower)]

Plant size, Mg/h (tons/h)	Uncontrolled	Dry collection (Fabric filter)	Wet dust suppression	Combination wet and dry
182 (200)[a]	477 (640)	554 (743)	478.1 (641.5)	495 (663)
273 (300)[b]	630 (845)	738 (989)	631.5 (847)	668 (896)
545 (600)[b]	1038 (1392)	1232 (1652)	1041.8 (1397)	1100 (1478)

[a] Extrapolated from data in Reference 4.

[b] Reference 4.

to wet dust suppression controls is about 0.2 percent. If a combination of both wet and dry controls were applied to each of the three model plants, the additional energy requirements would be 18, 38, and 62 kW (23, 51, and 86 hp), respectively, or about 6 percent.

5.5 IMPACT ON NOISE

Allowable noise levels and employee exposure times are specified by the Mining Enforcement and Safety Administration in Parts 55 and 56 of the August 7, 1974, Federal Register, Volume 39, No. 153. These limits require that potential noise problems be assessed and sound-dampening equipment be installed as required. No noise data were developed during this study; however, compared with the noise emanating from crushed-stone process equipment, any additional noise from control system exhaust fans is likely to be insignificant. Thus, no significant noise impact is anticipated as a result of the use of best demonstrated control technology at crushed-stone plants.

REFERENCES FOR CHAPTER 5

1. Development Document for Interim Final Effluent Limitations Guidelines and Standards of Performance - Mineral Mining and Processing Industry - Volume I (Minerals for the Construction Industry). Prepared by Versar, Incorporated, for the U.S. Environmental Protection Agency, Washington, D.C. EPA 440/1-75-/059. January 1975. p. V-3.

2. Source Testing Report - Essex Bituminous Concrete Corporation, Dracut, Massachusetts. Prepared by Roy F. Weston, Incorporated, Westchester, Pennsylvania, for U.S. Environmental Protection Agency. EPA Report No. 75 STN-2. December 27, 1974.

3. Development Document for Interim Final Effluent Limitation Guidelines and New Source Performance Standards for the Coal Mining Point Source Category. U.S. Environmental Protection Agency, Washington, D.C. EPA 440/1-76/057-a. May 1976. p. 85.

4. Standards Support and Environmental Impact Statement - An Investigation of the Best Systems of Emission Reduction for Qaurrying and Plant Process Facilities in the Crushed- and Broken-Stone Industry. Draft Report. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. August. August 1975.

6.0 COMPLIANCE TEST METHODS AND MONITORING TECHNIQUES

6.1 EMISSION MEASUREMENT METHODS

EPA relies primarily on Methods 5 and 9 for particulate matter measurements and visible emission observations (opacity) on stacks. Both are established reference or compliance methods and were used by EPA in obtaining the emissions data presented in Appendix A on fabric filter collectors used in the crushed-stone industry.

For fugitive emissions which are impractical to quantify, EPA has relied historically on visual methods, specifically on Method 9, to limit the opacity of visible emissions and force the application of controls. In this study, a new method in addition to Method 9 was used, Method 22. This draft method (see Appendix B) was specifically developed by EPA for the visual determination of fugitive emissions from material processing sources. Rather than assess the opacity of a visible emission, Method 22 determines the frequency at which a visible emission occurs during an observation period. A standard can thus be established which limits the percent of time during which visible emissions from a fugitive emissions source would be disallowed. Both methods were used in assessing the effectiveness of local exhaust hoods and wet dust suppression in reducing or preventing fugitive emissions from crushed-stone process facilities. Method 22 appears to be more applicable to intermittent sources of fugitive emissions while Method 9 is more applicable to continuous fugitive emission sources. In the case of fugitive dust sources which are typically large in area, EPA has no established procedures for either quantifying emissions from these sources or for assessing the visibility of emissions from these sources.

During the test program on fabric filter collectors, it was necessary to consider the potential problems associated with low levels of controlled emissions from the sources. Data from an EPA report indicate that particulate catches of about 50 mg are adequate to insure an error of no more than 10 percent.[1] Sampling trains with higher sampling rates, which are allowed by Method 5 and are commercially available, can be used to reduce the total sampling time and costs. Sampling costs of a test consisting of three particulate runs (the number normally spceified by performance test regulations) is estimated to be about $5000 to $7000. This estimate is based on sampling site modifications such as ports, scaffolding, ladders, platforms all costing less than $2000 and testing being conducted by contractors.

Because the outlet gas stream from the control devices used in this industry is generally well contained, no special sampling problems are anticipated.

Procedures for monitoring the process are discussed in Chapter 7.

6.2 MONITORING SYSTEMS AND DEVICES

The effluent streams from sources within the crushed-stone industry are essentially at ambient conditions. Therefore, the visible-emission-monitoring instruments proven adequate for power plants are also applicable for this industry. These instruments are covered by EPA performance standards contained in Appendix B of 40 CFR Part 60.

Equipment and installation costs are estimated to be $6000 to $8000, and annual operating costs including data recording and reduction, $8000 to $9000 for each stack.[2]

REFERENCES FOR CHAPTER 6

1. Mitchell, W.J. Additional Studies on Obtaining Replicate Particulate Samples from Stationary Sources. Unpublished report. Emission Monitoring and Support Laboratory, Environmental Protection Agency, Research Triangle Park, N. C., November 1973.

2. Standards Support and Environmental Impact Statement - An Investigation of the Best Systems of Emission Reduction for Quarrying and Plant Process Facilities in the Crushed- and Broken-Stone Industry. Draft Report,- U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. August 1975.

7.0 ENFORCEMENT ASPECTS

When formulating an air pollution control regulation, one must consider the aspects of enforcing that regulation. A regulation may be set for a specific operation, a combination of operations, or the entire processing or manufacturing facility. From a compliance evaluation standpoint, it is desirable to have separate standards for each affected operation in the industry. In practice, however, it often may be difficult to do so. This section identifies alternative air pollution control regulations and discusses enforcement aspects of these regulations.

7.1 PROCESS CONSIDERATIONS

The crushed-stone industry is characterized by a number of separate processing operations and emission sources, a variety of equipment types and configurations, and feed rate and composition variations. Some of the particulate emission sources such as quarrying, dumping, and storage are open sources. Other operations such as conveying and loading are frequently only partially enclosed, while crushing and screening can be more completely enclosed. In addition, the moisture content of the stone has a great effect on the particulate emissions. Process feed rates are not generally measured and some of the individual processes may operate on a very intermittent basis.

Process parameters that should be monitored to ensure that facilities are operated normally during enforcement tests or inspections include; the process throughput rate, the moisture content of the feed material and the approximate size distribution of the raw material and product. As previously mentioned, crushed-stone plants normally are not equipped with devices for measuring process weight rates. Based on normal screen pass-through and recycle rates, however, the amount of material entering a processing unit can be estimated. Guidelines are available for making such estimates.[1] An analysis of the moisture content of the material processed is very important to ensure that dust control at the time of the test is effected by the control system and not the result of unusually high moisture levels that are not normal for the plant. When the addition of moisture is part of the control system (e.g., wet dust suppression), a record should be made of the amount of added moisture required to effectively control emissions under the worst operating and climatic conditions. Moisture would have to be determined by taking samples of the feed streams for subsequent analysis.

7.2 FORMATS

Air pollution regulations for this industry can be expressed in terms of 1) quantitative particulate emission limits in terms of concentration, mass rate, or process-weight type units, 2) limits on visible emissions, 3) ambient air concentrations at the plant property line, 4) equipment standards that include specifications on process and/or control equipment, operating conditions, and monitoring requirements, and 5) compatible combinations of such measures.

7.2.1 Enforcement of Quantitative Emission Limits

Quantitative emission limits in the form of measured concentrations or limits on the emission rate per unit of time or throughput could be applied to crushed-stone plant process facilities (crushers, screens, conveyor transfer points, etc.) where emissions are captured by hoods or enclosures and vented to a control device for collection. Determination of particulate emissions or concentrations where control devices are used requires a source test on the exhaust of each control device. This involves utilization of available test methods (EPA Methods 1, 2, 4, 5), an experienced 2 to 3 person test crew and equipment, and an expenditure on the order of $5,000 to $7,000 per sampling location for a series of three runs. At times, a stack may have to be modified to provide a suitable sampling site. The cost per sampling location will decrease when more than one is tested at a plant. Due to the low particulate concentration expected at the outlet of a fabric filter system, the sampling time may have to be extended to insure adequate sample. Results from source tests provide accurate data on particulate concentration and emission rates.

As mentioned previously, crushed-stone plants normally are not equipped with devices for measuring process-weight rates. Consequently, process-weight type standards in which emissions are related to throughput may be difficult to enforce unless the plants are required to install process-weight rate monitors. In addition, in some instances more than one process may be vented to a common control device and only the total emissions from the connected processes can be determined.

No special problems exist with the enforcement of concentration or pollutant mass rate limits. It should be noted, however, that these limits are applicable to the control device only. As a result, other provisions (e.g., visible emission limits) will be needed to assure that capture systems are properly designed and maintained.

7.2.2 Enforcement of Visible Emission Limits

Visible emission limits are especially useful for limiting fugitive emissions from crushed-stone plant process facilities. Indeed, visible emission limits and equipment standards offer the only viable alternatives for limiting emissions from process facilities controlled by suppression techniques or for ensuring the effective capture of emissions at process facilities controlled by local ventilation. In addition, when used in conjunction with a quantitative emission limit on a control device, opacity limits can be used to ensure that the control device is properly operated and maintained.

The enforcement of visible emission limits is both feasible and inexpensive. Determinations can be made with a minimum of resources and require no special equipment. For opacity determinations using Method 9, only a single trained and certified observer is needed. In the case of

Method 22, which assesses the frequency of visible emissions from a source, no special training or certification is required and the equipment needs are limited to an accumulative type stop watch (see Appendix B). The only constraint on these methods is that readings cannot ususally be made at night, indoors under poor lighting conditions, or during periods of very inclement weather.

7.2.3 Enforcement of Equipment Standards[2]

Equipment standards relating to the design and installation of both equipment and control devices are feasible alternatives for limiting emissions from some of the stone industry processes. For example, enclosure of conveyor belts, the hooding of screens and crushers and venting through a fabric filter system, or the utilization of water spray systems may be specified. This format for regulation is not quantitative but does insure that emissions will be minimized through proper selection and utilization of equipment. Due to the variations in crushed-stone plants, an overall equipment standard may be difficult to apply. Such a regulation can be used in conjunction with both quantitative and visible emission limitations. Enforcement of equipment standards is accomplished through plant inspections and observation by an experienced and trained person. An inspection can be completed in one day by a one or two person team.

Proper operation and maintenance of specified equipment is also required to minimize emissions. Frequent plant inspections and review of maintenance records are required to ensure proper operation.

7.2.4 Enforcement of Fence-line Standards

Ambient air particulate measurements made at a plant's boundary can be used as an enforcement tool to help assess a plant's overall impact on particulate concentration. The feasibility of such an enforcement method is dependent on the plant configuration, the operating schedule, and on other particulate emission sources in the area. A number of samplers up and downwind of the property will be required, and these must be operated by trained personnel. Standard procedures which must be carefully followed and documented include:

(a) Location of sampling station(s),

(b) Records of meteorological conditions,

(c) Use of recommended sampling equipment,

(d) Careful determination of gas flow rate and sample time,

(e) Noting of any unusual conditions which may affect sample,

(f) Proper handling of the collected sample and recording of container and filter numbers.

The presence of other particulate sources in the area, especially fugitive sources such as dirt roads or construction activities, will also influence the usefulness of any measurements along a plant boundary. Wind speed and variability will also affect the usefulness of the results. An electrical supply is required to operate the samplers and this may present a problem at remote locations unless a portable electric generator is available.

REFERENCES FOR CHAPTER 7

1. Pit and Quarry Handbook and Buyers Guide, 68th Edition. Chicago, Pit and Quarry Publications, Inc. 1975-1976. p. A9-12.

2. Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions. Publication No. EPA-450/3-77-010. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina 27711.

8.0 REGULATORY OPTIONS

This chapter presents a summary of the available regulatory options for the control of particulate from crushed and broken stone production facilities. Both process sources and fugitive dust sources are discussed. The regulatory options are formulated based on the application of alternative control methods described in Chapter 3. Each option is discussed from the standpoints of applicability, emission reduction, cost, environmental impacts, and enforcement. In addition, applicable regulatory formats are presented and, where appropriate, achievable emissions are cited based on performance data presented in Chapter 3 and Appendix A.

8.1 REGULATORY OPTIONS FOR PROCESS SOURCES

The conversion of naturally occuring minerals into crushed stone products involves a series of interrelated physical operations. Quarrying, crushing, and size classification are common to almost all methods of mineral production. Particulates emanate from many sources (both process and fugitive) in a quarry and crushed stone plant. Process sources include drilling, crushing and grinding, conveying and elevating (transfer points), stockpiling (the actual operation itself) and screening.

Methods for control of plant generated emissions include wet dust suppression, dry collection and a combination of both.

8.1.1 Applicability and Performance of Control Techniques

Control Technique Descriptions--

Dry collection systems consist of an exhaust system with hoods and enclosures to confine and capture emissions, and ducting and fans to convey the captured emissions to a collection device where particulates are removed before the air stream is exhausted to the atmosphere. Depending on the physical layout of the plant, emission sources may be manifolded to a single centrally located collector or to a number of strategically placed units. Appropriate ventilation rates and hood configurations are discussed in Section 3.

The most commonly used collection device for crushed and broken stone production facilities is the fabric filter. Although high energy scrubbers and electrostatic precipitators could conceivably achieve results similar to those of a fabric filter, these methods are not currently used in the industry.

As discussed in Section 3, in most crushing plant applications, mechanical-shaker collectors (which require periodic shutdown for cleaning after 4 or 5 hours of oepration) are used. These units are normally equipped with cotton sateen bags and operated at an A/C ration of 2 or 3 to 1. A cleaning cycle, normally actuated automatically when the exhaust fan is turned off, usually requires only 2 or 3 minutes of bag shaking.

Fabric filters with continuous cleaning are used where it may be impractical to turn off the collector. Compartmented mechanical-shaker units or pulse-jet units may be used. Pulse-jet units normally have wool or synthetic felted bags as the filtering medium and can be operated at a higher filtering ratio (as high as 6 or 10:1).

In a wet dust-suppression system, dust emissions are controlled by spraying moisture (water or water plus a wetting agent) at critical dust-producing points in the process flow. This causes dust particles to adhere to larger stone surfaces or to form agglomerates too heavy to become, or remain airborne. Thus, the objective of wet dust suppression is not to fog an emission source with a fine mist to capture and remove emitted particulates, but rather to prevent their emission by keeping the material moist at all process stages.

Small quantities of specially formulated wetting agents or surfactants are blended with water to reduce its surface tension and consequently improve its wetting efficiency so that dust particulates may be suppressed with a minimum of added moisture.

Applicability--

Dry collection systems are applicable for all crushed stone process sources. Although retrofit of dry collection systems to existing plants (especially portable plants) may be somewhat difficult, it is judged to be technically feasible.

Wet suppression techniques can be used to control emissions at any process stage, or equipment where the quantity of moisture required to effectively suppress emissions can be tolerated. In some instances, where certain end products such as concrete aggregate are produced, wet dust suppression may not be applicable unless these materials are subsequently treated in a wash plant for fines removal because of the specifications on the content of fines. In addition, wet controls may not be functional at extremely low temperatures because of freezing.

Performance--

As discussed in Section 3, dry collection systems are capable of achieving high levels of emission reduction. Although impractical to quantify, if adequate hooding and ventilation rates are applied, essentially complete capture can be achieved. Visual observations made at crushed stone process facilities at three plants using dry collection techniques to control emissions showed that emissions escaping capture from properly designed and operated capture systems are slight with visible emissions typically occurring less than 10 percent of the time and seldom exceeding 5 percent opacity. Based on uncontrolled emission estimates and measured outlet data, the application of fabric filter collectors (either mechanical shaker or pulse-jet type) should achieve greater than 99 percent collection efficiency on captured emissions from crushed stone process facilities. Mass particulate measurements conducted by EPA at the outlet of twelve fabric filter collectors at five crushed stone plants averaged 0.011 g/Nm^3 (0.005 gr/dscf) and did not exceed 0.034 g/Nm^3 (0.015 gr/dscf). In addition, visual observations made at the outlet of each of the fabric filters tested showed no visible emissions at 10 of the 12 and only slight emissions ranging from 0 to 5 percent opacity at the other two with the highest six minute average recorded being 1.0 percent.

As noted in Section 3, a quantitative assessment of the effectiveness of wet dust suppression techniques in reducing mass particulate emissions from crushed and broken stone process facilities is not practical. However, visual observations can be used to provide some indication of performance. Visual observations made by EPA at numerous process facilities at five plants where particulate emissions are controlled by wet dust suppression techniques showed that, where properly designed and operated, wet suppression systems offer a viable control alternative to dry collection at process facilities (both crusher and non-crusher sources) that can tolerate the amount of added moisture necessary for effective control. The results obtained indicate that emissions from crushers are generally greater than those from non-crusher sources. Visual observations made at twelve crushers including jaw, impact and cone type crushers showed that emissions were generally continuous (visible over 70 percent of the time on average) and typically exceeded 10 percent opacity. In contrast, emissions from non-crusher sources (screens and conveyor transfer points) were generally intermittent (visible less than 90 percent of the time) and typically less than one percent in opacity (six-minute average).

Although not specifically evaluated, it is reasonable to assume that performance levels for combination systems is essentially equivalent to that demonstrated for the use of dry collection or wet suppression alone.

8.1.2 Cost, Energy, and Environmental Considerations

Table 8-1 summarizes the estimated energy, envionmental, and cost impacts for application of dry collection and wet suppression to the three model plants presented in Section 4. These incremental impacts are computed against an uncontrolled emission baseline.

Air--

The application of dry collection systems to crushed and broken stone process sources should result in substantial reduction in emissions. Based on the estimates developed in Section 5.1, greater than 98 percent reduction over uncontrolled emissions is projected.

Since particulate emissions from process facilities controlled by wet suppression techniques are impractical to quantify, no quantitative data are available on their emission reduction potential except to say that comparable emission reductions can apparently be achieved using wet dust suppression or combination of wet and dry systems where these control systems are properly operated and maintained.

Water Pollution--

Dry collection techniques using fabric filters generate no water effluent. Water used for wet suppression is absorbed by the material processed. It is therefore concluded that application of air pollution control technology to the crushed and broken stone processes has no significant impact on water quality

Solid Waste--

Solid waste in the form of fine stone dust generated by the application of dry collection methods at crushed and broken stone processes can be sold or used for a variety of purposes. Alternatively, the dust can be disposed of in isolated locations in the plant quarry with no subsequent air pollution problem provided the waste pile is controlled by one of the methods discussed in Section 3. Thus, wet suppression and dry collection control systems have a negligible impact as far as solid waste disposal is concerned.

Energy--

The only significant increase in energy consumption over an uncontrolled plant occurs when a fabric filter is used for particulate collection. The additional energy is for operation of fans, air compressors, and screw conveyors associated with operation of the fabric filter. The increase in energy is estimated to range from 16 to 19 percent higher than the uncontrolled plant, as shown in Table 8-1.

In contrast, additional energy required to operate the wet suppression system is less than one percent.

For a combination wet-dry collection system the increase in energy consumption is about 6 percent for each plant size.

Noise--

Compared with the noise emanating from crushed stone process equipment, additional noise from control system exhaust fans is likely to be insignificant.

Cost--

The overall costs of the control alternatives for crushed stone production are shown in Table 8-1. Use of fabric filters for dry collection is the most expensive control alternative (both capital investment and annualized costs) followed by the combination wet-dry collection system, with the wet suppression system being the least expensive control option.

The capital investment (in 1976 dollars) for fabric filters at the three model plant sizes, ranges from \$145,000 to \$340,000 compared to a range of \$131,000 to \$188,000 for combination systems, and \$66,000 to \$76,000 for wet suppression.

Unit costs follow the same pattern, with dry collection costs ranging from 9.5 to 13.7¢/Mg (8.5-12.5¢/ton) of production, combination systems from 5.1 to 10.6¢/Mg (4.6-9.6¢/ton), and wet suppression from 2.0 to 4.5¢/Mg (1.8-4.1¢/ton).

Thus, combination systems are less expensive than dry collection alone, and wet suppression is the least costly control alternative, where it can be used.

8.1.3 Alternative Formats and Emission Limits

The various formats available for regulating particulate emissions were discussed in Section 7.

For dry collection, regulations should limit emissions both from collection device and at the points of capture.

Alternative formats for the collection device include quantitative emission limits in concentration, mass rate and process-weight rate units; limits on opacity of visible emissions;

and equipment standards. Alternative formats for regulating fugitive emissions at capture points include limits on the opacity or duration of visible emissions and equipment standards.

Enforcement of quantitative emission limits in process weight units would require that devices which measure process weight rates be installed on belts feeding process equipment. Concentration units would be simpler to enforce than the process-weight standard, since they do not require that a weight measuring device be installed. As noted in Section 8.1.1, data obtained on fabric filters controlling crushed stone process facilities indicate that an outlet loading of performance 0.03 g/dry m^3 (0.013 gr/dscf) or less, can be achieved. In addition, the opacity of emissions discharged by the collection device could be limited to 1 percent (six minute average). For fugitive emissions discharged at capture points (i.e., hoods and enclosures), a visible emission limitation which would limit visible emissions to no more than 10 percent of the time is achievable.

For equipment standards (fabric filters in this instance), the air-to-cloth ratio, cleaning method, pressure drop, configuration of capture hoods and enclosures, and capture velocities would need to be specified (see Section 3). Compliance with these specifications would be determined by the control agency as a part of their permit or licensing program.

For wet dust suppression, regulations would limit emissions at the point of generation. Quantitative emission limits do not seem reasonable for wet suppression control because an emission capture system would need to be built to measure the decrease in emissions and, while technically possible, testing would be costly. As a result, alternative formats that could be applied are limited to visible emission limits on the opacity or duration of emissions and equipment standards.

As noted in Section 8.1.1, visible emissions from non-crusher sources controlled by wet dust suppression were found to be intermittent while those from crushers were generally continuous. Because of this distinction, a different format for limiting visible emissions should be applied to each class of sources. For non-crusher sources characterized by intermittent emissions, a visible emission limitation which limits the duration of emissions is more appropriate than an opacity limit. For crusher sources with continuous emissions, an opacity limit presents the only alternative. Based on the performance data presented in Section 3 and discussed in Section 8.1.1, an achievable standard for non-crusher sources would limit visible emissions to no more than 10 percent of the time. For crushers, visible emissions could be limited to 15 percent opacity. These visible emission limits should insure that sufficient water is used in the wet suppression system to provide effective control of particulate.

If equipment standards were applied, specifications would include configuration of nozzles, spray pressure, and the amount of moisture to be added.

8,2 REGULATORY OPTIONS FOR FUGITIVE DUST SOURCES

Fugitive emissions are generated by blasting, loading, hauling, stockpiling (e.g., free fall), and also are windblown from roads, plant yards, and stockpiles. Various treatments include watering, wet dust suppression, surface treatment with chemical dust suppressants, soil stabilization, and paving. Table 3-1 summarizes control options from fugitive dust sources in the crushed stone industry.

8.2.1 Control Technique Descriptions, Applicability and Performance

The most commonly used fugitive dust control methods used are summarized in this section.

Control Technique Descriptions and Applicability--

No effective method is available for controlling fugitive emissions from blasting operations, except to try and schedule blasting operations during conditions of low wind and low inversion potential.

Quarry loading operations are sometimes controlled by watering as are hauling operations. Other control techniques used to control haul roads include oiling of roads, the application of hygroscopic chemicals (substances that absorb moisture from the air), the use of soil stabilizers, consisting of a water dilutable emulsion of either synthetic or petroleum resins that act as an adhesive or binder, and paving of roads.

Wet dust suppression is sometimes used for control of fugitive emissions from stockpiles, as are devices designed to reduce the free-fall distance of the materials, such as stone ladders, telescopic chutes, and hinged boom stacker conveyors. However, watering is the most commonly used technique for active stockpiles. Soil stabilizers are sometimes used with reasonable success on inactive stockpiles.

Chemical suppression and covering are the two methods used for control of fugitive emissions from conveying operations, covers being the most effective.

Loadout operations are generally uncontrolled, but at some installations attempts are made to wet the material either prior to or during loading. Enclosing the area under loading bins also reduces the potential for windblown emissions.

Fugitive emissions from plant yard areas are generally uncontrolled, and in cases where some control is exercised, similar methods to those used for haul roads are employed.

Performance--

Since minimal data are available for quantifying emissions from fugitive dust sources, the performance of various methods of control cannot be accurately estimated. The effectiveness of the most commonly used methods depends on the amount of water or chemical applied, the frequency of application, weather conditions, and conditions of the road or material being treated.

8.2.2 Cost, Energy, and Environmental Considerations

This section summarizes the environmental, energy, and cost impacts of available data on control techniques for reducing fugitive emissions from crushed stone sources presented in Section 4.

Air Impact--

As stated previously, fugitive dust sources are typically large in area and emissions are discharged to the atmosphere in an unconstrained manner, rather than through a stack. Therefore, quantitative measurement of these emissions would be very difficult. Consequently, estimates are not available on the impact of implementing controls for fugitive dust.

Water Impact--

No data are available to assess the impact on water quality associated with various roadway treatments. However, it is believed that the impact on water quality would be negligible.

Solid Waste Impacts--

The control techniques used for control of fugitive dust emissions from crushed stone processes would have no impact on solid waste.

Energy Impact--

Minimal data are available on increased energy use related to use of control techniques for fugitive dust control. It is expected, however, that the energy impact would be small in comparison to the energy requirements for quarry and plant operations.

Cost Impact--

Of the five control techniques listed in Section 4 (See Tables 4-12 and 4-12a) for controlling fugitive emissions from unpaved roads, the capital investment for truck speed reduction at $150,000 is 5 times more expensive than other techniques, such as paving, vacuuming, and oiling: and 10 times more expensive than the most inexpensive technique, watering. The annual costs of truck speed reduction at $87,500/yr are 3 to 10 times more expensive than other competing techniques.

Costs of retrofitting covers on existing conveyors is estimated at $35 to $70/ft of conveyor length. Since conveyor covers require little maintenance, annual costs consist largely of indirect capital charges.

Typical capital costs of control for storage piles are estimated at $20,000 per 9.1 m (30-ft) pile for a stone ladder, $26,000 to $42,000 per telescoping chute, $772 per Mg ($700 per ton) of throughput for a movable stacker, and $105 to $263 per m^3 ($80 to $200 per yd^3) for enclosures (see Table 4-14). Again, annual costs depend mainly on remaining plant life and the cost of capital.

Sprinkler systems for stockpiles are estimated to cost from a few thousand dollars to $20,000, depending on the plant. Costs of spraying storage piles are estimated to range from $0.01 to $0.06 per Mg ($0.05/ton), depending on the chemical used, the number of storage piles, and the frequency of spraying.

All of the above costs are in 1976 dollars.

8.2.3 Alternative Formats and Emission Limits

Quantitative emission limits are not considered applicable to fugitive dust sources in the crushed stone industry because no practical method of measurement is available.

The use of visible emission limits in terms of opacity and as percent of time when the emission limits are visible is especially useful for fugitive sources of particulate. However, care must be taken to obtain readings under representative conditions, because of the intermittent operation of some processes and the variation in emissions caused by climatic conditions.

In formulating specific visible emission regulations for fugitive dust emissions in the crushed stone industry, test programs would be required for monitoring opacity of visible emissions for such control techniques as different vehicle speeds and weights, frequency of watering or oiling, and effect of weather conditions.

In the absence of visible emissions data, and the lack of an established, practical method to measure the amount of particulate being emitted by fugitive dust sources, the equipment standard or work practice standard may be the most suitable format. For fugitive dust sources, this format is in the form of a "performance standard," that specifies the manner in which the sources should be constructed or operated. Equipment standards can be specified for some fugitive dust source, such as enclosures for open conveyors. These standards are not quantitative but would ensure that emissions will be minimized through proper selection and utilization of equipment.

Ambient air measurements made at a plant's boundary can be used to help assess a plant's overall impact, including fugitive dust emissions, on particulate concentration. Enforcement problems may arise because of the presence of other particulate sources in the area, such as unpaved roads or construction activities that generate fugitive emissions. These sources may adversely influence the usefulness of measured data.

As far as a general regulation covering fugitive dust emissions is concerned, many states use a performance-type regulation patterned after the one contained in 40 CFR 51, Appendix B, for regulating fugitive particulate emissions. The typical state regulation recommends that "reasonable precautions" be taken to minimize the potential of fugitive dust emissions and suggests some general techniques to achieve this goal. The enforcement problems associated with this type of "reasonable precautions" regulation can be alleviated by the careful specification of precautions, i.e., source specific performance standards.

A regulation may require the implementation of one or more of the control alternatives. For example, a regulation may require that all conveyors be covered, or the regulating agency may desire to exercise its discretion, depending upon factors such as the proximity of dust emitting operations to human habitations or activities and atmospheric conditions that might affect the dispersion of particulate matter. The following model performance standard regulation for fugitive dust sources associated with crushed-stone production incorporates source specific control measures with a provision for discretion;

> (a) No person shall operate or maintain, or cause to be operated or maintained, any premise, open area, right-of-way, storage pile of materials, or any other process that involves any handling, transporting, or disposition of any material or substance likely to be scattered by the wind, without taking reasonable precautions, as approved by the regulating agency, to prevent particulate matter from becoming airborne.

(b) In obtaining approval under subsection (a) of this section, the regulating agency may impose one or more of the measures and any operating conditions it deems necessary to attain and maintain compliance with the provisions of this section.

8.3 REGULATORY OPTIONS FOR DRILLING

Two methods are generally used to control particulate emissions from drilling operations: water injection and aspiration to a control device.

8.3.1 Control Technique Descriptions, Applicability and Performance

Water injection is a technique in which water and a wetting agent or surfactant is forced into the compressed air stream that flushes the drill cuttings from the hole. The water injection produces a mist that dampens the stone particles and causes them to agglomerate, and drop at the drill collar rather than becoming airborne.

The use of a wetting agent allows the use of less water for effective control, by reducing the surface tension of the untreated water.

Dry collection systems are also used to control drilling emissions. A shroud or hood encircles the drill rod at the hole collar, and a vacuum captures emissions and vents them through a flexible duct to a control device, most commonly a fabric filter, preceded by a settling chamber.

Fabric filter performance should be equivalent to that achieved on other crushed stone process facilities. As indicated in Chapter 3, visible emission tests for a rotary drill equipped with a fabric filter showed opacities of 0 to 5 percent at the fabric filter and less than 20 percent at the capture point for greater than 75 percent of the observation time.

8.3.2 Environmental, Energy, and Cost Considerations

The environmental, energy, and cost impacts of applying fabric filters as a dry collection technique or water injection as a wet collection technique have not been assessed.

8.3.3 Alternative Formats and Emission Limits

Applicable formats for limiting particulate emissions from drilling operations controlled by dry collection include quantitative emission limits, visible emission limits, and equipment standards.

A concentration limit applied to the fabric filter should be equivalent to that achievable by other fabric filters applied on other crushed stone process facilities. Limitations on visible emissions (e.g., less than 10 percent opacity from the fabric filter and less than 20 percent from the hole collar), would ensure proper operation of the fabric filter and would ensure maintenance of an adequate aspiration rate at the capture point. However, since drilling is an intermittent operation and emissions can vary because of climatic conditions, care must be taken to obtain readings under representative conditions.

Equipment standard specifications that could be required are the air-to-cloth ratio, cleaning method, pressure drop, and aspiration rate.

Applicable regulation formats for water injection are visible emissions and equipment specifications. Limitations on visible emissions (less than 20 percent opacity at the hole collar) will ensure proper design, operation, and maintenance of water injection systems.

The only important equipment specification is the rate of water injection to ensure that sufficient water is used for effective collection.

8.4 SUMMARY

A matrix summarizing the environmental and cost impacts resulting from the application of alternative emission control systems is presented in Table 8-2. Impacts are rated as beneficial or adverse; the magnitude as negligible, small, moderate, or large; and the duration as short term, long term, or irreversible.

Table 8-2. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS

Alternative emission control systems	Air impact	Water impact	Solid waste impact	Energy impact	Noise impact	Occupational health impact	Cost impact
Wet suppression for crushed stone plant process facilities	+3**	0	0	-1	0	+3**	-2**
Dry collection for crushed stone plant process facilities	+3**	0	-2	-2	-1**	+3**	-2 to -3**
Combination wet and dry for crushed stone plant process facilities	+3**	0	-2	-2	-1**	+3**	-2**
Dry collection for drilling equipment	+2**	0	-1	-1	-1**	+2**	-2**
Liquid injection for drilling equipment	+2**	0	0	-1	0	+2**	-1**

Key:	+	Beneficial impact	1	Negligible impact	*	Short-term impact
	-	Adverse impact	2	Small impact	**	Long-term impact
	0	No impact	3	Moderate impact		

APPENDIX A

SOURCE TEST DATA

A test program was undertaken by EPA to evaluate available techniques for controlling particulate emissions from crushed stone plant process facilities including crushers, screens and material handling operations, especially conveyor transfer points. Both dry control (capture and collection) and wet suppression techniques were evaluated. In addition, the use of capture and collection on a drilling operation were also evaluated. Presented in this appendix is a description of each facility tested, and complete test data summaries for both mass particulate measurements and visible emission observations.

DRY COLLECTION

Twelve baghouse collectors which control emissions from plant facilities at five crushed stone installations were tested. A baghouse collector used to control particulate emissions from a drilling operation at a limestone quarry was also tested. Salient facts on each of the baghouse collectors tested including the filtering ratio, the volumetric flow-rate handled and a description of the process facilities serviced are summarized in Table A-1. A minimum of three test runs were conducted, using EPA Reference Method 5 for the determination of particulate matter, on each of the baghouses tested. During these tests, testing was stopped and restarted to allow for intermittent process shut-downs and upsets (no stone).

Table A. PROCESS FACILITIES CONTROLLED BY BAGHOUSE UNITS TESTED

Facility	Rock type processed	Baghouse specifications			Process facilities controlled
		Type	Filtering ratio	Capacity scfm	
A1	Limestone	Jet pulse	5.3 to 1	26472	Primary impact crusher
A2	Limestone	Jet pulse	7 to 1	15811	Primary screen
A3	Limestone	Jet pulse	7 to 1	2346	Conveyor transfer point
A4	Limestone	Jet pulse	5.2 to 1	10532	Secondary crusher (cone) and screen
B1	Limestone	Shaker	3.1 to 1	5784	Primary impact crusher
B2	Limestone	Shaker	2.1 to 1	18197	Scalping screen, secondary cone crusher, hammer mill, two tertiary cone crushers, two finishing screens, five storage bins, and six conveyor transfer points
C1	Limestone	Shaker	2.3 to 1	7473	Primary jaw crusher (discharge), scalping screen, and hammer mill
C2	Limestone	Shaker	2.0 to 1	6543	Two finishing screens and two conveyor transfer points
D1	Traprock	Shaker	2.8 to 1	31863	Scalping screen, secondary cone crusher, two sizing screens, two tertiary cone crushers and several conveyor transfer points
D2	Traprock	Shaker	2.8 to 1	25960	Finishing screen and several conveyor transfer points
E1	Traprock	Jet pulse	5.2 to 1	14748	Two sizing screens, four tertiary cone crushers and several conveyor transfer points
E2	Traprock	Jet pulse	7.5 to 1	21122	Five finishing screens and eight storage bins
F	Limestone	Shaker (manual)	2.5 to	663	Rotary drill

Where the process weight rate was undeterminable at a specific plant facility, as in most instances, the process weight through the primary crushing stage was monitored to assure that the plant was operating at or near normal capacity. Also determined was the moisture content of the processed stone at each plant (except for plant A) to ensure that emissions were controlled by the dust collection system and not by abnormally high moisture content in the material processed. Results of the front-half catch (probe plus filter) for each sample run conducted are shown in Figures A-1 and A-2 in terms of concentration and mass rate respectively. Excluding the measurements made at facility F, the emission concentration of the control devices tested averaged 0.005 gr/dscf and did not exceed 0.013 gr/dscf. The results of the measurements performed at facility F (rotary drill) averaged 0.039 gr/dscf. It is suspected that since this collector utilized a manually operated shaker mechanism, it may have been subjected to over-cleaning and, consequently, poor filter cake buildup.

In addition to the particulate measurements described above, visible emissions observations were also made. The opacity of the emissions exhausted by each of the 12 baghouses tested was recorded in accordance with EPA Reference Method 9 procedures. No visible emissions were observed from the fabric filters at plants A, C, D and E. Slight emissions ranging from 0 to 5 percent opacity were observed at B1 and B2. The highest six minute average recorded at each of these

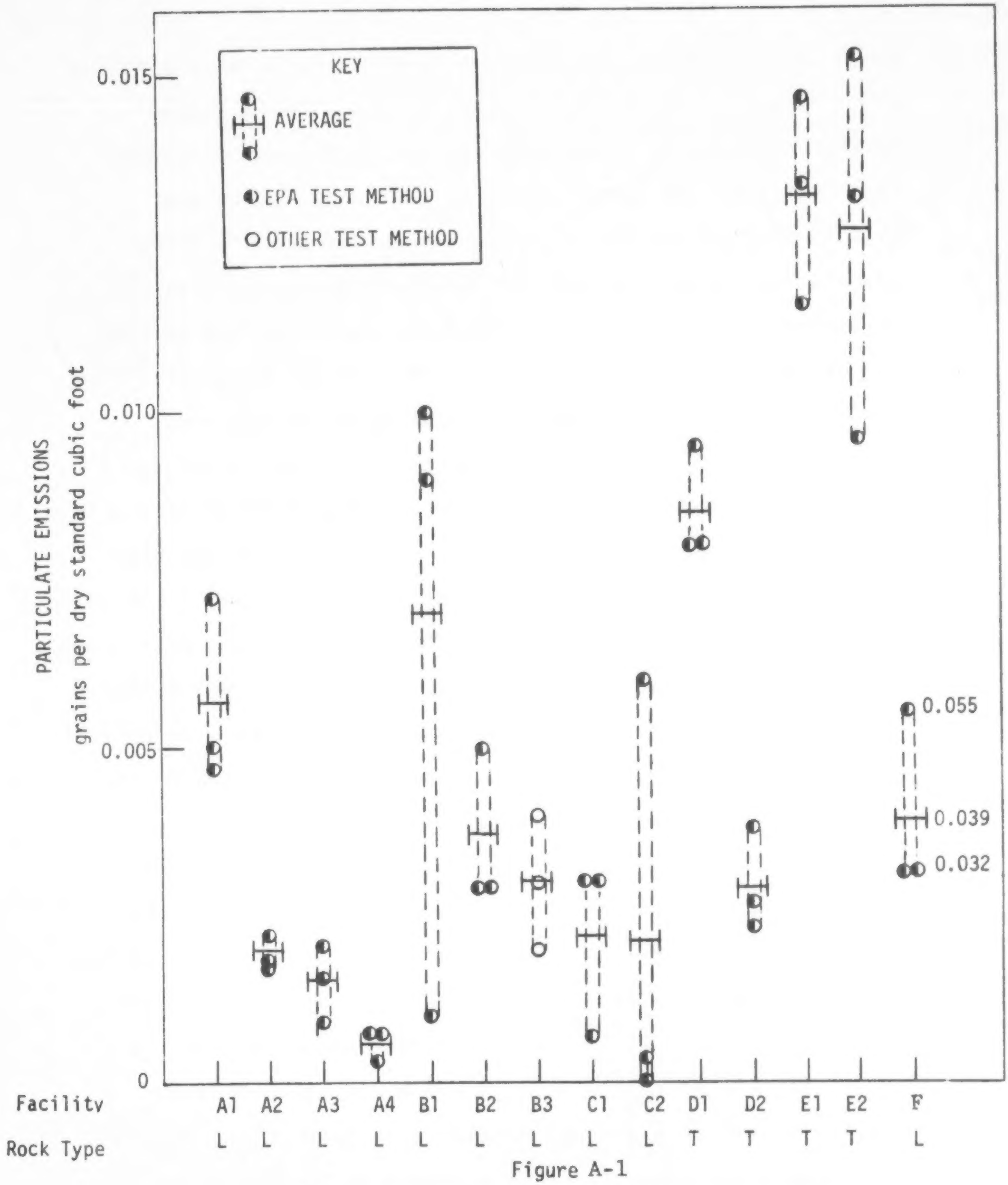

Figure A-1

Particulate emissions from crushed stone facilities.

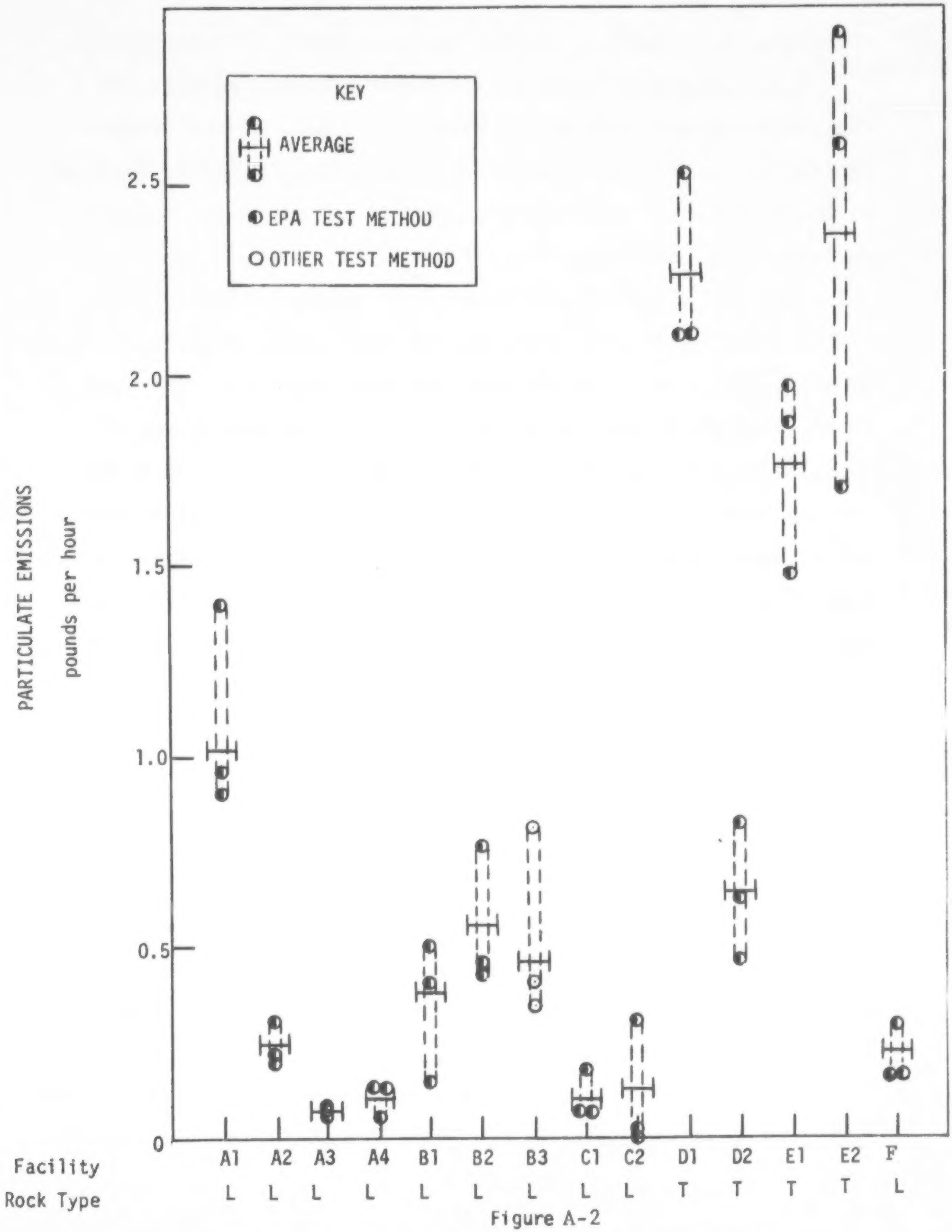

Figure A-2

Particulate emissions from crushed stone facilities.

three baghouses was 1.0 and 0.8 percent opacity, respectively.

Observations of visible emissions were also made at the capture hoods and enclosures installed on many of the process facilities controlled by the baghouses tested at plants A, B and D to determine the presence and opacity of emissions escaping capture. Eight crushers, six screens, one conveyor transfer point and one surge bin were observed. Again, EPA Reference Method 9 was used. The results, however, are presented in terms of the total time emissions were observed equal to or greater than a specified opacity rather than in six minute averages.

Table A-2 lists the specific process facilities observed and the results obtained in terms of the percent of time over a stated observation period that visible emissions occurred. In most cases (10 of 16) no visible emissions were observed over the entire observation period. At the six process facilities where visible emissions were observed, the emissions observed were slight (seldom exceeding 5 percent opacity) and occurred less than 10 percent of the time.

WET DUST SUPPRESSION

Due to the nature of wet dust suppression, the quantitative measurement of mass particulate emissions at process facilities controlled by wet dust suppression techniques is impractical. However, some assessment of the effectiveness of this technique can be made by visual observation.

Visual observations were made at numerous process facilities (crusher, screens and conveyor transfer points) at five installa-

TABLE A-2. SUMMARY OF VISIBLE EMISSION OBSERVATIONS AT CAPTURE HOODS OR ENCLOSURES ON CRUSHED-STONE PLANT PROCESS FACILITIES

Plant/Rock type processed		Process facility	Accumulated observation time (minutes)	Accumulated emission time (minutes)	Percent of time with visible emissions
A	Crushed limestone	Primary impact crusher discharge	240	4	1
		Conveyor transfer point	166	3	2
B	Crushed limestone	Scalping screen	287	45	15
		Surge bin	287	3	1
		Secondary cone crusher No. 1	231	23	10
		Secondary cone crusher No. 2	231	0	0
		Secondary cone crusher No. 3	231	0	0
		Hammer mill	287	0	0
		3-deck finishing screen (L)	107	4	4
		3-deck finishing screen (R)	107	0	0
D	Crushed stone	No. 1 tertiary gyrasphere cone crusher	170	0	0
		No. 2 tertiary gyrasphere cone crusher	170	0	0
		Secondary standard cone crusher	170	0	0
		Scalping screen	210	0	0
		Secondary (2-deck) sizing screen	210	0	0
		Secondary (3-deck) sizing screen	210	0	0

tions where particulate emissions generated are controlled by wet dust suppression techniques. The installations included two portable and three stationary plants. The visual observations were made using both EPA Reference Methods 9 and 22. A listing of the process facilities observed and a summary of the results obtained are presented in Table A-3. Complete results are presented in the Tables herein.

The results obtained indicate that emissions from crushers are generally greater than those from non-crusher sources. Visual observations made at twelve crushers including jaw, impact and cone type crushers showed that emissions were generally continuous (visible over 70 percent of the time on average) and typically exceeded 10 percent opacity. In contrast, emissions from non-crusher sources (screens and conveyor transfer points) were generally intermittent (visible less than 90 percent of the time) and typically less than one percent in opacity (six-minute average).

DESCRIPTION OF FACILITIES

A1. Primary crushing stage incorporating a pan feeder, vibrating grizzly, impact breaker, T-bar belt feeder and a primary belt conveyor. The impactor is rated at 1,000 TPH and used to reduce run-of-quarry limestone (cement rock) to

TABLE A - 3
SUMMARY OF VISIBLE EMISSION OBSERVATIONS FROM CRUSHED STONE PROCESS FACILITIES CONTROLLED BY WET DUST SUPPRESSION

		EPA Method 22		EPA Method 9		
Plant	Process Facilities	Observation time (minutes)	Percent of time Emissions visible	Observation time (minutes)	Highest Six-Minute Average	Average Opacity
G	Primary Jaw Crusher	20	69	102	21	11
	Scalping Screen	--	--	60	12	10
	Secondary Impact Crusher	20	96	60	15	11
	Secondary Screen	60	0	60	0	0
	Tertiary Cone Crusher	--	--	120	25	13
	Conveyor Transfer Point	60	1	60	3	< 1
H	Primary Jaw Crusher	60	53	120	18	8
	Scalping Screen	60	36	120	10	4
	Conveyor Transfer Point	60	49	120	14	9
	Secondary Screen	120	0	120	2	1
	Secondary Cone Crusher	30	95	120	39	26
	Finishing Screens	120	0	120	< 1	0
I	Scalping Screen	120	3	120	3	2
	Primary Jaw Crusher	30	93	120	17	11
	Conveyor Transfer Point	30	12	60	5	2
	Secondary Screens	120	9	120	5	1
	Secondary Cone Crusher	30	99	120	17	14
	Finishing Screens	120	0	120	1	< 1
	Conveyor Transfer Point	60	0	60	0	0
	Convevor Transfer Point	60	2	60	3	< 1
J	Primary Jaw Crusher	60	5	120	3	1
	Scalping Screen (2-deck)	120	0	120	0	0
	Secondary Cone Crusher (4 1/2')	30	68	120	5	4
	Secondary Screen	120	10	120	4	< 1
	Secondary Cone Crusher (5 1/2')	30	25	120	15	8
	Conveyor Transfer Point	120	0	120	0	0
	Conveyor Transfer Point	120	0	120	0	0
K	Primary Jaw Crusher	30	65	120	11	8
	Conveyor Transfer Point	120	2	120	4	< 1
	Secondary Screen (3-deck)	120	0	120	0	0
	Secondary Cone Crusher (4 1/4')	30	100	120	23	17
	Storage Bin	120	0	120	2	< 1

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minus 2 1/2-inch. Particulate emissions generated at various points are captured and vented to a jet pulse type baghouse for collection.

A2. Primary screen used for scalping the primary crusher product of facility A1. The plus 2 1/2-inch oversize is chuted to a belt conveyor and returned to the primary for recrushing. The screen throughs are also discharged to a conveyor and transported to a storage facility. Particulate emissions generated from the top of the screen, which is totally enclosed, and from both chute-to-belt transfer points are aspirated to a jet pulse baghouse for collection. Particulate emission measurements were conducted simultaneously with those at facility A1. Sampling during all three test runs reported herein was overisokinetic.

A3. Conveyor transfer point at the tail of an overland conveyor, also located at installation A1. The 30-inch belt conveyor has a 900 TPH capacity at a belt speed of 700 FPM. The transfer point is enclosed and emissions are vented to a small baghouse unit for collection.

A4. The secondary crushing and screening stage at installation A1 consisting of a vibrating screen and a cone crusher. Minus 2 1/2-inch material is fed to the screen at about 165 TPH where it is separated in two fractions, plus

3/4-inch and minus 3/4-inch. The oversize fraction is discharged to the cone crusher and reduced to 3/4-inch. The crusher product and screen throughs are then conveyed to a milling circuit. Dust control is effected by capturing and venting emissions from the screen and crusher to a jet pulse baghouse for collection.

B1. Primary impact crusher used for the initial reduction of run-of-quarry limestone rock to three inches. The normal production rate through this primary crushing stage is 350 TPH. From the discharge hopper underneath the impact crusher and from the discharge hopper/primary conveyor belt transfer point, particulate emissions are vented to a fabric filter for collection. The fabric filter is mechanically shaken twice daily for cleaning.

B2. Secondary and tertiary crushing and screening facilities at the same installation as B1. These consist of a scalping screen, a 4-foot cone crusher, two 3-foot cone crushers, a hammermill used to produce agstone and two final sizing screens. The plant has a 300 TPH designed capacity, crushing to minus 1 1/2-inch, including, 60 TPH of agstone. Throughout this plant emissions from dust producing points are captured by hoods and enclosures, and vented to a fabric filter for collection. The collector is mechanically shaken twice daily for cleaning. Pickup points include the top of the scalping screen, both the feed and the discharge of all three cone crushers, the discharge of the hammermill, the top of both finishing screens, five product bins and six conveyor transfer points.

B3. The same facility as B2, except that particulate emission measurements were made using an in-stack filter. Testing was conducted simultaneously with that described in B2.

C1. Limestone crushing plant consisting of a primary jaw crusher, scalping screen and hammermill. The rated capacity of the plant is 125 TPH. End products produced range from minus 1 1/2-inch dense-graded road base stone to minus 1/8-inch screenings. Particulate emissions are controlled by a mechanical shaker type baghouse. Ventilation points include the primary crusher discharge, the scalping screen throughs/stacking conveyor transfer point, and both the hammermill feed and discharge. Tests were conducted using EPA Methods 5 and 9.

C2. Two 3-deck vibrating screens used for final sizing at the same installation as C1. Both screens are totally enclosed. Particulate emissions, which are collected from the top of both screens, from the feed to both screens, and from both the head and tail of a shuttle conveyor between the screens, are vented to a mechanical shaker type baghouse.

D1. Secondary and tertiary crushing and screening facilities used for processing traprock at 250 TPH. The process facilities include a scalping screen, a 4-foot secondary cone crusher, two sizing screens and two 4-foot tertiary cone crushers. All process facilities are enclosed and particulate emissions are vented to one of two baghouses for collection. The baghouses are exhausted through a common stack.

D2. Finishing screen at the same installation as facility D1. The screen is totally enclosed and emissions are vented to a fabric filter. Emissions are collected from the top of the screen enclosure, all screen discharge points, and several conveyor transfer points. Tests conducted were identical to those at D1 and were performed simultaneously.

E1. Tertiary crushing and screening facilities at a 375 TPH traprock installation. Process facilities include two sizing screens, four 4 1/4-foot cone crushers and several conveyor transfer points. Both screens are enclosed and emissions are aspirated from the top of the enclosures and from the throughs discharge. The tertiary cone crushers are hooded and vented at both feed and discharge points. Captured emissions are vented to a jet pulse type baghouse for collection. Although desirable, the pressure drop across the baghouse could not be monitored because the pressure gauge was inoperative.

E2. Five screens used for final sizing, and eight storage bins at the same installation as E1. All screens and bins are totally enclosed and emissions are vented to a jet pulse type baghouse for collection. Tests conducted were identical to and performed simultaneously with those at facility E1.

F. Rotary drill used to drill 5" X 80' blastholes at a limestone quarry. Particulate emissions were aspirated from the drill collar to a baghouse for collection. Only one point was sampled and the duration of each test run coincided with the time required to drill a hole. Visible emission observations were made concurrently with the particulate measurements.

G. Facility G produces crushed stone used primarily for road construction purposes. The processing operation is located in the bottom of an open quarry. The quarried materials are carried by truck to the upper rim of the pit where they are dumped into hoppers which feed the processing equipment. The finished product is transported back out of the quarry by belt conveyor.

Visible emission measurements were conducted at the primary (jaw), secondary (impact), and tertiary (cone) crushers, two process screens, and one conveyor transfer point by means of EPA Reference Methods 9 and 22. All process sources of emissions are directly or indirectly controlled by means of a wet suppression system.

H. This facility produces two grades of rock for road-base and decorative stone, respectively. The ore is obtained from an open mining operation at the top of a mountain, and the process equipment is permanently installed in a decending arrangement from the mine site to the bottom of the mountain. The processed rock is accumulated in bins at the lower level for subsequent truck loading.

Visible emission measurements using the same techniques as Facility Q were conducted at the primary (jar), and secondary (cone) crushers, three process screens, and one conveyor transfer point all controlled by means of a wet suppression system.

I. A fully portable crushing plant processes bank-run material for road construction and as concrete component. Ore is removed from a gravel bank and trucked to the bank top for dumping into the initial screens before the primary crushers. Wet suppression techniques are used to control fugitive dust emanating from the processing of the material.

EPA Reference Methods 9 and 22 were used to measure visible emissions from primary (jaw), and secondary (cone) crushers, three process screens, and two conveyor transfer points.

J. The facility produces two grades of crushed granite. The plant is relatively new with all process equipment located at ground level. One jaw crusher, two cone crushers, two process screens and two conveyor transfer points are all directly or indirectly controlled by means of wet suppression systems.

EPA Reference Methods 9 and 22 were employed to measure visible emissions emanating from the above named process sources.

K. A large semi-portable rock crushing facility processing large-size grades of crushed limestone was tested for visible emissions by means of EPA Reference Methods 9 and 22.

The sources tested were the primary and secondary (cone) crushers, one process screen, one conveyor transfer point, and one storage bin. All sources tested are controlled by wet dust suppression.

TABLE 1
FACILITY A1
Summary of Results

Run Number	1	2	3	Average
Date	6/10/74	6/11/74	6/12/74	-
Test Time - Minutes	400	320	240	320
Production Rate - TPH(1)	995	1027	1010	1011
Stack Effluent				
Flow rate - ACFM	26430	26653	27142	26472
Flow rate - DSCFM	22351	22140	22502	22331
Temperature - °F	81.0	88.0	88.0	85.7
Water vapor - Vol. %	2.5	3.0	3.3	2.9
Visible Emissions at Collector Discharge - % Opacity		SEE TABLES 2 - 3		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00471	0.00504	0.00727	0.00567
gr/ACF	0.00398	0.00419	0.00602	0.00473
lb/hr	0.90	0.96	1.40	1.07
lb/ton	0.00091	0.00102	0.00139	0.00111
Total catch				
gr/DSCF(2)	-	0.00597	0.00839	0.00718
gr/ACF	-	0.00495	0.00695	0.00595
lb/hr	-	1.13	1.62	1.38
lb/ton	-	0.00121	0.00160	0.00140

(1) Based on throughput through primary crusher.
(2) Back-half sample for run number 1 was lost.

Reference 1.

TABLE 2

FACILITY A1

Summary of Visible Emissions

Date: 6/4/74 - 6/5/74

Type of Plant: Crushed Stone - Primary Crusher

Type of Discharge: Stack

Distance from Observer to Discharge Point: 75 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 14 ft.

Direction of Observer from Discharge Point: N.E.

Description of Background: Grey building

Description of Sky: Clear

Wind Direction: East

Wind Velocity: 0 - 5 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 6/4/74 - 78 minutes
6/5/74 - 210 minutes

SUMMARY OF AVERAGE OPACITY(1)

	Time		Opacity	
Set Number	Start	End	Sum	Average
1 through 6	8:50	9:26	0	0
7 through 9	11:23	11:41	0	0
10 through 13	12:12	12:36	0	0
14 through 48	8:11	11:41	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time: Not Available

Reference 1.

FACILITY A1

SUMMARY OF VISIBLE EMISSIONS(1)

Date: 7/8/75 - 7/9/75

Type of Plant: Crushed stone (cement rock)

Type of Discharge: Fugitive

Location of Discharge: Primary impact crusher (discharge conveyor or transfer point)

Height of Point of Discharge: 6 feet

Distance from Observer to Discharge Point: 15 feet

Description of Background: Grey wall

Height of Observation Point: Ground level

Description of Sky: N.A. (indoors)

Direction of Observer from Discharge Point: SE

Wind Direction: N.A.

Wind Velocity: No wind (indoors)

Color of Plume: White

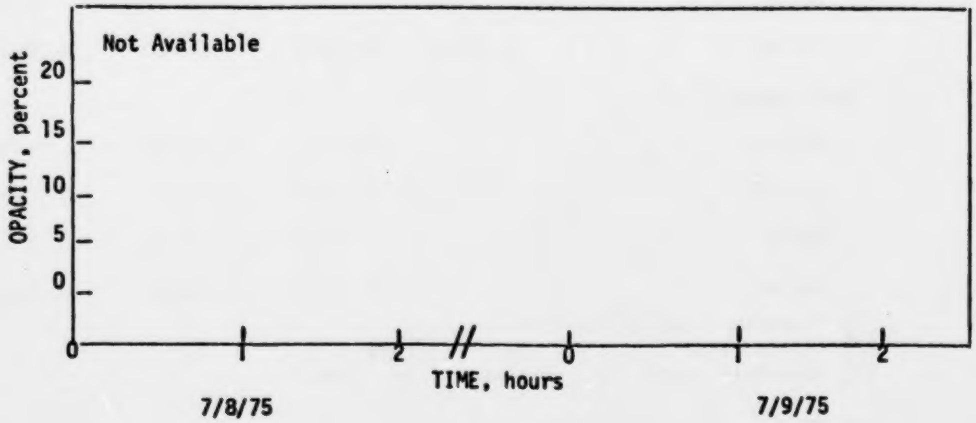
Detached Plume: No

Duration of Observation: 7/8/75 - 2 hours
7/9/75 - 2 hours

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	3	30	55	-	-
10	0	30	60	-	-
15	0	15	65	-	-
20	0	15	70	-	-
25	0	0	75	-	-
30	-	-	80	-	-
35	-	-	85	-	-
40	-	-	90	-	-
45	-	-	95	-	-
50	-	-	100	-	-

Sketch Showing How Opacity Varied With Time:



(1) Two observers made simultaneous readings, the greater of their readings is reported.

Reference 2.

TABLE 4
FACILITY A2
Summary of Results

Run Number	1	2	3	Average
Date	6/10/74	6/11/74	6/12/74	-
Test Time - Minutes	400	320	240	320
Production Rate - TPH(1)	965	1023	1056	1015
Stack Effluent				
Flow rate - ACFM	15797	15771	15866	15811
Flow rate - DSCFM	13368	13246	13196	13270
Temperature - °F	90.0	90.0	94.0	91.3
Water vapor - Vol. %	1.4	2.1	2.5	2.0
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 5		
Particulate Emissions (2)				
Probe and filter catch				
gr/DSCF	0.00176	0.00188	0.00222	0.00195
gr/ACF	0.00149	0.00158	0.00184	0.00164
lb/hr	0.20	0.21	0.25	0.22
lb/ton	0.00021	0.00024	0.00024	0.00023
Total catch (3)				
gr/DSCF	-	0.00235	0.00314	0.00275
gr/ACF	-	0.00197	0.00261	0.00224
lb/hr	-	0.27	0.36	0.32
lb/ton	-	0.00030	0.00034	0.00032

(1) Throughput through primary crusher.
(2) All three test runs were over-isokinetic.
(3) Back-half sample for run number 1 was lost.

Reference 1.

TABLE 5

FACILITY A2

Summary of Visible Emissions

Date: 6/10/74 - 6/11/74

Type of Plant: Crushed Stone - Primary Screen

Type of Discharge: Stack

Distance from Observer to Discharge Point: 60 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 10 ft.

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: Clear

Wind Direction: Southwest

Wind Velocity: 0 - 2 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 6/10/74 - 192 minutes
6/11/74 - 36 minutes

SUMMARY OF AVERAGE OPACITY(1)

	Time		Opacity	
Set Number	Start	End	Sum	Average
1 through 11	10:35	11:41	0	0
12 through 32	12:30	2:36	0	0
33 through 38	9:40	10:16	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time: Not Available

Reference 1.

TABLE 6
FACILITY A3
Summary of Results

Run Number	1	2	3	Average
Date	6/10/74	6/11/74	6/12/74	-
Test Time - Minutes	360	288	288	312
Process Weight Rate - TPH	910	915	873	899
Stack Effluent				
Flow rate - ACFM	2303	2313	2422	2346
Flow rate - DSCFM	1900	1902	2003	1935
Temperature - °F	98.0	101.0	97.0	98.7
Water vapor - Vol. %	2.4	2.4	2.3	2.4
Visible Emissions at Collector Discharge - % Opacity		SEE TABLES 7 and 8		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00095	0.00162	0.00207	0.00155
gr/ACF	0.00078	0.00134	0.00171	0.00128
lb/hr	0.02	0.03	0.04	0.03
lb/ton	0.00002	0.00003	0.00004	0.00003
Total catch (1)				
gr/DSCF	-	0.00190	0.00259	0.00224
gr/ACF	-	0.00156	0.00214	0.00185
lb/hr	-	0.03	0.04	0.035
lb/ton	-	0.00003	0.00005	0.00004

(1) Back-half sample for run number 1 was lost.

Reference 1.

TABLE 7

FACILITY A3

Summary of Visible Emissions

Date: 6/11/74

Type of Plant: Crushed Stone - Conveyor Transfer Point

Type of Discharge: Stack

Distance from Observer to Discharge Point: 60 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground-level

Height of Point of Discharge: 8 ft.

Direction of Observer from Discharge Point: North

Description of Background: Grey apparatus

Description of Sky: Clear

Wind Direction: Westerly

Wind Velocity: 0 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY(1)

Set Number	Time		Opacity	
	Start	End	Sum	Average
1 through 30	10:40	1:40	0	0
31 through 40	1:45	2:45	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time: Not Available

Reference 1.

TABLE 8

FACILITY A3

SUMMARY OF VISIBLE EMISSIONS (1)

Date: 7/9/75 - 7/10/75

Type of Plant: Crushed stone (cement rock)

Type of Discharge: Fugitive

Location of Discharge: Conveyor (transfer point)

Height of Point of Discharge: 8 feet

Distance from Observer to Discharge Point: 50 feet

Description of Background: Sky

Height of Observation Point: 6 feet

Description of Sky: Partly cloudy

Direction of Observer from Discharge Point: SE

Wind Direction: South

Wind Velocity: 3 - 5 mph

Color of Plume: White

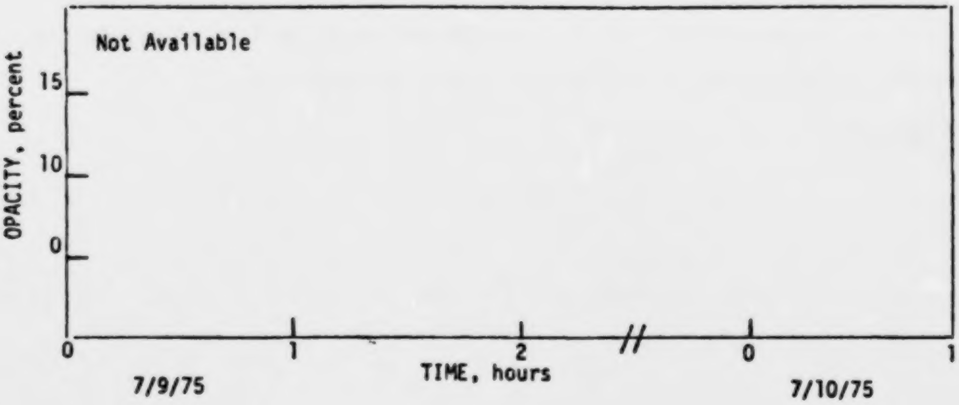
Detached Plume: No

Duration of Observation: 7/9/75 - 106 minutes
7/10/75 - 60 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	3	0	55	-	-
10	0	45	60	-	-
15	0	30	65	-	-
20	0	0	70	-	-
25	-	-	75	-	-
30	-	-	80	-	-
35	-	-	85	-	-
40	-	-	90	-	-
45	-	-	95	-	-
50	-	-	100	-	-

Sketch Showing How Opacity Varied With Time:



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(1) Two observers made simultaneous readings, the greater of their readings is reported.

Reference 2.

TABLE 9
FACILITY A4
Summary of Results

Run Number	1	2	3	Average
Date	6/6/74	6/7/74	6/8/74	-
Test Time - Minutes	320	320	320	320
Production Rate - TPH	170	162	152	163
Stack Effluent				
Flow rate - ACFM	10579	9971	11045	10532
Flow rate - DSCFM	9277	8711	9656	9214
Temperature - °F	81.0	77.0	80.0	79.3
Water vapor - Vol. %	2.3	2.2	2.1	2.2
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 10		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.00036	0.00075	0.00074	0.00062
gr/ACF	0.00031	0.00065	0.00065	0.00054
lb/hr	0.03	0.06	0.06	0.05
lb/ton	0.00017	0.00034	0.00041	0.00031
Total catch				
gr/DSCF	0.00047	0.00104	-	0.00678
gr/ACF	0.00041	0.00095	-	0.00068
lb/hr	0.04	0.08	-	0.06
lb/ton	0.00022	0.00050	-	0.00034

Reference 1.

TABLE 10
FACILITY A4
Summary of Visible Emissions

Date: 6/6/74

Type of Plant: Crushed Stone - Secondary Crushing and Screening

Type of Discharge: Stack	Distance from Observer to Discharge Point: 100 ft.
Location of Discharge: Baghouse	Height of Observation Point: Ground-level
Height of Point of Discharge: 15 ft.	Direction of Observer from Discharge Point: North
Description of Background: Sky	
Description of Sky: Clear	
Wind Direction: Variable	Wind Velocity: 0 to 10 mi/hr.
Color of Plume: None	Detached Plume: No
Duration of Observation: 240 minutes	

SUMMARY OF AVERAGE OPACITY(1)

	Time		Opacity	
Set Number	Start	End	Sum	Average
1 through 30	10:40	1:40	0	0
31 through 40	1:45	2:45	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time: Not Available

Reference 1.

TABLE 11

FACILITY B1

Summary of Results

Run Number	1	2	3	Average
Date	10/29/74	10/30/74	10/30/74	-
Test Time - Minutes	180	120	120	140
Production Rate - TPH(1)	324	359	375	353
Stack Effluent				
Flow rate - ACFM	5154	6121	6078	5784
Flow rate - DSCFM	4998	5896	5753	5549
Temperature - °F	70	76	83	76.3
Water vapor - Vol. %	1.80	1.87	2.06	1.91
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 12		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.009	0.001	0.010	0.007
gr/ACF	0.012	0.004	0.011	0.009
lb/hr	0.402	0.072	0.500	0.325
lb/ton	0.0012	0.0002	0.0013	0.0007
Total catch				
gr/DSCF	0.009	0.001	0.010	0.007
gr/ACF	0.011	0.003	0.011	0.008
lb/hr	0.496	0.180	0.553	0.408
lb/ton	0.0015	0.0005	0.0015	0.0012

(1) Throughput through primary crusher.

Reference 3.

TABLE 12

FACILITY B1

Summary of Visible Emissions(1)

Date: 10/29/74 - 10/30/74

Type of Plant: Crushed Stone - Primary Crusher

Type of Discharge: Stack

Distance from Ovserver to Discharge Point: 15 ft.

Location of Discharge: Baghouse

Height of Observation Point: Ground level

Height of Point of Discharge: 25 ft.

Direction of Observer from Discharge Point: West

Description of Background: Grey quarry wall

Description of Sky: Clear to cloudy

Wind Direction: Northwesterly

Wind Velocity: Not available

Color of Plume: White

Detached Plume: No

Duration of Observation: 10/29/74 - 180 minutes
10/30/74 - 234 minutes

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
10/29/74				
1	10:30	10:36	10	0.4
2	10:36	10:42	20	0.8
3	10:42	10:48	25	1.0
4	10:48	10:54	15	0.6
5	10:54	11:00	15	0.6
6	11:00	11:06	5	0.2
7	11:06	11:12	10	0.4
8	11:12	11:18	25	1.0
9	11:18	11:24	20	0.8
10	11:24	11:30	15	0.6
11	11:30	11:36	25	1.0
12	11:36	11:42	30	1.2
13	11:42	11:48	15	0.6
14	1:15	1:21	0	0
15	1:21	1:27	15	0.6
16	1:27	1:33	5	0.2
17	1:33	1:39	5	0.2
18	1:39	1:45	0	0
19	1:45	1:51	0	0
20	1:51	1:57	0	0
21	1:57	2:03	5	0.2
22	2:03	2:09	5	0.2
23	2:09	2:15	0	0
24	2:15	2:21	0	0
25	2:21	2:27	0	0
26	2:27	2:33	5	0.2
27	2:33	2:39	5	0.2
28	2:39	2:45	0	0
29	2:45	2:51	0	0
30	2:51	2:57	10	0.4
10/30/74				
31	9:05	9:11	0	0
32	9:11	9:17	0	0
33	9:17	9:23	0	0
34	9:23	9:29	0	0
35	9:29	9:35	5	0.2
36	9:35	9:41	10	0.4
37	9:41	9:47	0	0
38	9:47	9:53	0	0
39	9:53	9:59	5	0.2
40	9:59	10:05	0	0
41	10:05	10:11	0	0
42	10:11	10:17	0	0
43	10:17	10:23	0	0
44	10:28	10:34	0	0
45	10:34	10:40	10	0.4
46	10:40	10:46	5	0.2
47	10:58	11:04	0	0
48	11:04	11:10	5	0.2
49	11:10	11:16	10	0.4
50	11:24	11:30	0	0
51	11:30	11:36	0	0
52	1:02	1:08	0	0
53	1:08	1:14	0	0
54	1:14	1:20	0	0
55	1:20	1:26	10	0.4
56	1:26	1:32	0	0
57	1:32	1:38	5	0.2
58	1:38	1:44	0	0
59	1:44	1:50	0	0
60	1:50	1:56	0	0
61	1:56	2:02	5	0.2
62	2:02	2:08	0	0
63	2:08	2:14	5	0.2
64	2:14	2:20	5	0.2
65	2:20	2:26	0	0
66	2:26	2:32	0	0
67	2:39	2:45	0	0
68	2:45	2:51	5	0.2
69	2:51	2:57	0	0

Reference 3. (1) Highest of two observers

TABLE 13
FACILITY B2
Summary of Results

Run Number	1	2	3	Average
Date	10/31/74	10/31/74	11/11/74	-
Test Time - Minutes	108	108	108	108
Production Rate - TPH	270	270	270	270
Stack Effluent				
Flow rate - ACFM	19684	18921	16487	18197
Flow rate - DSCFM	18296	17638	15681	17205
Temperature - °F	92.0	96.0	79.0	87.0
Water vapor - Vol. %	1.95	1.92	2.01	1.96
Visible Emissions at Collector Discharge - % Opacity	SEE TABLES 14 - 22			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.003	0.005	0.003	0.0037
gr/ACF	0.003	0.005	0.003	0.0037
lb/hr	0.427	0.753	0.457	0.546
lb/ton	0.0016	0.0028	0.0017	0.0020
Total catch				
gr/DSCF	0.006	0.006	0.007	0.0063
gr/ACF	0.005	0.006	0.007	0.0060
lb/hr	0.916	0.978	0.955	0.946
lb/ton	0.0034	0.0036	0.0035	0.0035

Reference 3

TABLE 14

FACILITY B2

Summary of Visible Emissions (1)

Date: 10/31/74 - 11/1/74

Type of Plant: Crushed Stone - Secondary and Tertiary Crushing and Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 30 ft.

Location of Discharge: Baghouse

Height of Observation Point: 5 ft.

Height of Point of Discharge: 8 ft.

Direction of Observer from Discharge Point: East

Description of Background: Sky

Description of Sky: Clear to partly cloudy

Wind Direction: Southeasterly

Wind Velocity: Not available

Color of Plume: White

Detached Plume: No

Duration of Observation: 10/31/74 - 240 minutes
11/1/74 - 106 minutes

SUMMARY OF AVERAGE OPACITY

Date	Set Number	Time Start	Time End	Opacity Sum	Opacity Average
10/31/74	1	9:27	9:33	5	0.2
	2	9:33	9:39	10	0.4
	3	9:39	9:45	5	0.2
	4	9:45	9:51	0	0
	5	9:51	9:57	5	0.2
	6	9:57	10:03	5	0.2
	7	10:03	10:09	10	0.4
	8	10:09	10:15	5	0.2
	9	10:15	10:21	20	0.8
	10	10:21	10:27	0	0
	11	10:27	10:33	0	0
	12	10:33	10:39	0	0
	13	10:39	10:45	5	0.2
	14	10:45	10:51	5	0.2
	15	10:51	10:57	10	0.4
	16	10:57	11:03	0	0
	17	11:03	11:09	5	0.2
	18	11:09	11:15	0	0
	19	11:15	11:21	0	0
	20	11:21	11:27	10	0.4
	21 through 40	1:09	3:09	0	0
11/1/74	41 through 56	8:11	9:47	0	0

Readings ranged from 0 to 5 percent opacity.

(1) Higher of two observers

Reference 3.

Table 15

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Secondary Cone Crusher (#1)

Height of Point of Discharge: 25 ft.

Distance from Observer to Discharge Point: 45 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 2 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: North

Wind Direction: East

Wind Velocity: 5-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 231 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	23	0	55		
10	0	45	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

Table 16

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Secondary Cone Crusher (#2)

Height of Point of Discharge: 25 ft.

Distance from Observer to Discharge Point: 45 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 2 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: North

Wind Direction: East

Wind Velocity: 5-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 231 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	15	55		
10	0	0	60		
15	-	-	65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

Table 17

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Secondary Cone Crusher (#3)

Height of Point of Discharge: 25 ft.

Distance from Observer to Discharge Point: 45 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 2 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: North

Wind Direction: East

Wind Velocity: 5-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 231 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

Table 18

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75 - 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Surge Bin

Height of Point of Discharge:

Distance from Observer to Discharge Point: 150 ft.

Description of Background: Sky & Equipment

Height of Observation Point: 15 ft.

Description of Sky: Clear

Direction of Observer from Discharge Point: SE

Wind Direction: South

Wind Velocity: 5 mph

Color of Plume: White

Detached Plume: No

Duration of Observation:
6/30/74 - 234 minutes
7/1/75 - 53 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	2	0	55		
10	1	15	60		
15	-	30	65		
20	-	-	70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

Table 19

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75 - 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Scalping screen

Height of Point of Discharge: 50 ft.	Distance from Observer to Discharge Point: 150 ft.
Description of Background: Sky & Equipment	Height of Observation Point: 15 ft.
Description of Sky: Clear	Direction of Observer from Discharge Point: SE
Wind Direction: South	Wind Velocity: 5 MPH
Color of Plume: White	Detached Plume: no

Duration of Observation: 6/30/75 - 234 minutes
7/1/75 - 53 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	44	45	55		
10	9	45	60		
15	3	0	65		
20	0	30	70		
25	-	-	75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

Table 20

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 6/30/75 - 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: Hammermill

Height of Point of Discharge:	Distance from Observer to Discharge Point: 150 ft.
Description of Background: Sky & Equipment	Height of Observation Point: 15 ft.
Description of Sky: Clear	Direction of Observer from Discharge Point: SE
Wind Direction: South	Wind Velocity: 5 mph
Color of Plume: White	Detached Plume: No

Duration of Observation: 6/30/75 - 234 minutes
7/1/75 - 53 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: (3-Deck) Finishing Screen (left)

Height of Point of Discharge: 40 '

Distance from Observer to Discharge Point: 75 ft.

Description of Background: Hazy Sky

Height of Observation Point: Ground level

Description of Sky: Clear

Direction of Observer from Discharge Point: West

Wind Direction: Southeast

Wind Velocity: 5-15 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 107 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	4	30	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

Table 22

FACILITY B2

SUMMARY OF VISIBLE EMISSIONS

Date: 7/1/75

Type of Plant: Crushed stone (limestone)

Type of Discharge: Fugitive

Location of Discharge: (3-Deck) Finishing screen (right)

Height of Point of Discharge: 40 ft.

Distance from Observer to Discharge Point: 75 ft.

Description of Background: Hazy sky

Height of Observation Point: Ground level

Description of Sky: Clear

Direction of Observer from Discharge Point: West

Wind Direction: Southeast

Wind Velocity: 5-15 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 107 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	15	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 4

TABLE 23
FACILITY B3
Summary of Results

Run Number	1	2	3	Average
Date	10/31/74	11/1/74	11/1/74	-
Test Time - Minutes				
Production Rate - TPH	270	270	270	270
Stack Effluent				
Flow rate - ACFM	18674	18405	16238	17772
Flow rate - DSCFM	17335	17186	15466	16662
Temperature - °F	92	90	79	87
Water Vapor - Vol. %	2.13	1.73	1.87	1.91
Visible Emissions at Collector Discharge - % Opacity				
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.002	0.004	0.003	0.003
gr/ACF	0.002	0.004	0.003	0.003
lb/hr	0.355	0.614	0.411	0.460
lb/ton	0.0013	0.0023	0.0015	0.0017
Total catch(1)				
gr/DSCF				
gr/ACF				
lb/hr				
lb/ton				

(1) No analysis of bark-half on in-stack filter tests.

Reference 3.

TABLE 24
FACILITY C1
Summary of Results

Run Number	1	2	3	Average
Date	11/19/74	11/21/74	11/22/74	-
Test Time - Minutes	120	240	240	200
Production Rate - TPH(1)				
Stack Effluent				
Flow rate - ACFM	7340	7560	7520	7473
Flow rate - DSCFM	7260	7720	7800	7593
Temperature - °F	66.0	38.0	44.0	49.3
Water vapor - Vol. %	1.0	0.4	0.1	0.5
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 25		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.003	0.0007	0.003	0.0012
gr/ACF	0.003	0.0007	0.003	0.0012
lb/hr	0.18	0.05	0.17	0.10
lb/ton	0.001	0.0004	0.001	0.0008
Total catch				
gr/DSCF	0.007	0.001	0.003	0.0037
gr/ACF	0.007	0.001	0.003	0.0037
lb/hr	0.43	0.09	0.21	0.24
lb/ton	0.003	0.0008	0.002	0.0019

(1) Throughput through primary crusher.

Reference 5.

TABLE 25
FACILITY C1
Summary of Visible Emissions(1)

Date: 11/21/74

Type of Plant: Crushed Stone - Primary and Secondary Crushing and Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 100 ft.

Location of Discharge: Baghouse

Height of Observation Point: 50 ft.

Height of Point of Discharge: 40 ft.

Direction of Observer from Discharge Point: N.W.

Description of Background: Dark Woods

Description of Sky: Overcast

Wind Direction: Easterly

Wind Velocity: 10 to 30 mi/hr.

Color of Plume: White

Detached Plume: No

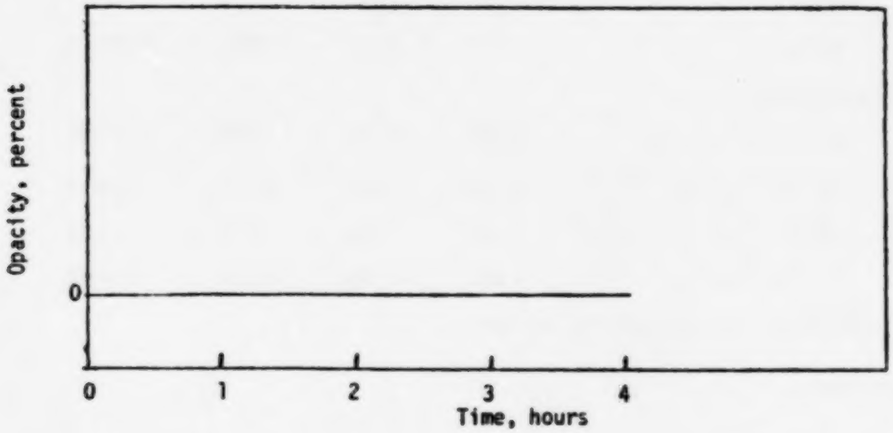
Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY(2)

	Time		Opacity	
Set Number	Start	End	Sum	Average
1 through 40	12:10	4:10	0	0

Readings were 0 percent opacity during the observation period.

Sketch Showing How Opacity Varied With Time:



---

(1) Two observers made simultaneous readings.

Reference 5.

TABLE 26
FACILITY C2
Summary of Results

Run Number	1	2	3	Average
Date	11/19/74	11/21/74	11/22/74	-
Test Time - Minutes	120	240	240	200
Production Rate - TPH(1)	132	119	127	126
Stack Effluent				
Flow rate - ACFM	6220	6870	6540	6543
Flow rate - DSCFM	6260	6880	6700	6613
Temperature - °F	62.0	50.0	51.0	54.3
Water vapor - Vol. %	0.4	0.3	0.1	0.27
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 27		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.006	0.00003	0.0004	0.00214
gr/ACF	0.006	0.00003	0.004	0.00214
lb/hr	0.31	0.002	0.02	0.111
lb/ton	0.002	0.00002	0.0002	0.00074
Total catch				
gr/DSCF	0.008	0.0006	0.0009	0.0032
gr/ACF	0.009	0.0007	0.001	0.0057
lb/hr	0.46	0.04	0.05	0.18
lb/ton	0.003	0.0003	0.0004	0.0012

(1) Throughput through primary crusher.

Reference 5.

TABLE 27

FACILITY C2

Summary of Visible Emissions(1)

Date: 11/21/74

Type of Plant: Crushed Stone - Finishing Screens

Type of Discharge: Stack

Distance from Observer to Discharge Point: 200 ft.

Location of Discharge: Baghouse

Height of Observation Point: 50 ft.

Height of Point of Discharge: 40 ft.

Direction of Observer from Discharge Point: N.W.

Description of Background: Dark woods

Description of Sky: Overcast

Wind Direction: Easterly

Wind Velocity: 10 to 30 mi/hr.

Color of Plume: White

Detached Plume: ———

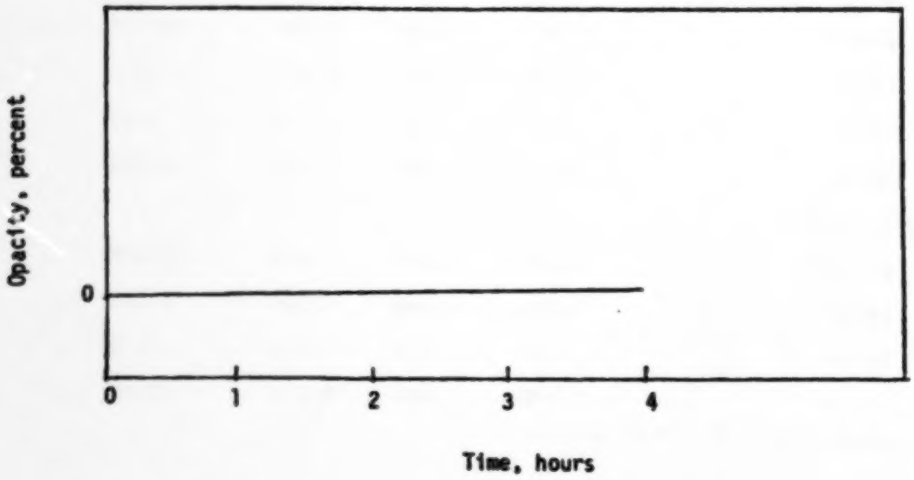
Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1 through 40	12:10	4:10	0	0

Readings were 0 percent opacity during the observation period.

Sketch Showing How Opacity Varied With Time:



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(1) Two observers made simultaneous readings.

TABLE 28
FACILITY D1
Summary of Results

Run Number	1	2	3	Average
Date	9/17/74	9/18/74	9/19/74	-
Test Time - Minutes	240	240	240	240
Production Rate - TPH(1)	225	230	220	225
Stack Effluent				
Flow rate - ACFM	31830	31810	31950	31863
Flow rate - DSCFM	31370	30650	31230	31083
Temperature - °F	66.0	71.0	68.0	68.3
Water vapor - Vol. %	1.2	1.7	1.6	1.5
Visible Emissions at Collector Discharge - % Opacity		SEE TABLES 29-35		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0095	0.0081	0.0080	0.0085
gr/ACF	0.0094	0.0078	0.0078	0.0083
lb/hr	2.55	2.13	2.13	2.27
lb/ton	0.0113	0.0093	0.0097	0.0101
Total catch				
gr/DSCF	0.0100	0.0085	0.0086	0.0090
gr/ACF	0.0096	0.0082	0.0084	0.0088
lb/hr	2.69	2.23	2.30	2.41
lb/ton	0.0120	0.0097	0.0105	0.107

(1) Throughput through primary crusher.

Reference 6.

TABLE 29
FACILITY D1
Summary of Visible Emissions(1)

Date: 9/17/74

Type of Plant: Crushed Stone - Secondary and Tertiary Crushing & Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 300 ft.

Location of Discharge: Baghouse

Height of Observation Point: 40 ft.

Height of Point of Discharge: 55 ft.

Direction of Observer from Discharge Point: S.E.

Description of Background: Trees

Description of Sky: Partly Cloudy

Wind Direction: Northerly

Wind Velocity: 5 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

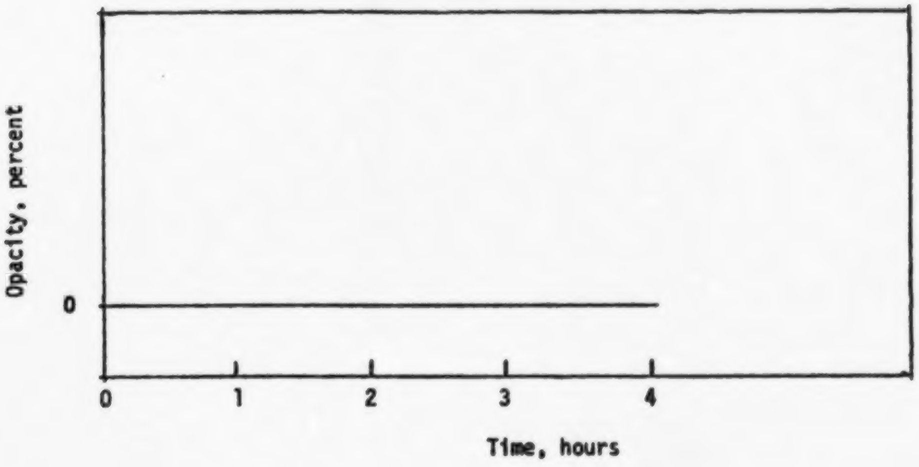
Duration of Observation: 240 minutes

SUMMARY OF AVERAGE OPACITY(2)

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
1 through 40	9:10	1:00	0	0

Readings were 0 percent opacity during the period of observation.

Sketch Showing How Opacity Varied With Time:



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(1) Two observers made simultaneous readings.

Reference 6.

Table 30.

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/8/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Tertiary gyrasphere cone crusher (S)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Machinery

Height of Observation Point: ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: West

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 170 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 7

Table 31

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/8/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Tertiary gyrashere cone crusher (N)

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Machinery

Height of Observation Point: ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: West

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 170 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 7

Table 32

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/8/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Secondary standard cone crusher

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Machinery

Height of Observation Point: Ground level

Description of Sky: Overcast

Direction of Observer from Discharge Point: West

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 170 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.	Opacity, Percent	Total Time Equal to or Greater Than Given Opacity Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 7

Table 33

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/9/75	
Type of Plant: Crushed stone (traprock)	
Type of Discharge: Fugitive	
Location of Discharge: Scalping screen	
Height of Point of Discharge:	Distance from Observer to Discharge Point: 30 ft.
Description of Background: Equipment	Height of Observation Point: 15 ft.
Description of Sky: Overcast	Direction of Observer from Discharge Point: North
Wind Direction: Southwest	Wind Velocity: 0-10 mph
Color of Plume: White	Detached Plume: No
Duration of Observation: 210 minutes	

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 7

Table 34

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/9/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Secondary (2-Deck) sizing screens

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft.

Description of Background: Equipment

Height of Observation Point: 15 ft.

Description of Sky: Overcast

Direction of Observer from Discharge Point: North

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 210 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 7

Table 35

FACILITY D1

SUMMARY OF VISIBLE EMISSIONS

Date: 7/9/75

Type of Plant: Crushed stone (traprock)

Type of Discharge: Fugitive

Location of Discharge: Secondary (3-Deck) sizing screens

Height of Point of Discharge:

Distance from Observer to Discharge Point: 30 ft

Description of Background: Equipment

Height of Observation Point: 15 ft.

Description of Sky: Overcast

Direction of Observer from Discharge Point: North

Wind Direction: Southwest

Wind Velocity: 0-10 mph

Color of Plume: White

Detached Plume: No

Duration of Observation: 210 minutes

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55		
10	-	-	60		
15			65		
20			70		
25			75		
30			80		
35			85		
40			90		
45			95		
50			100		

Reference 7

TABLE 36
FACILITY D2
Summary of Results

Run Number	1	2	3	Average
Date	9/17/74	9/18/74	9/19/74	-
Test Time - Minutes	240	240	240	240
Production Rate - TPH(1)	225	230	220	225
Stack Effluent				
Flow rate - ACFM	26790	26260	24830	25960
Flow rate - DSCFM	26200	25230	24170	25200
Temperature - °F	69.0	74.0	72.0	71.7
Water vapor - Vol. %	1.3	1.6	1.3	1.4
Visible Emissions at Collector Discharge - % Opacity	SEE TABLES 37 and 38			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0027	0.0038	0.0023	0.0029
gr/ACF	0.0027	0.0036	0.0022	0.0028
lb/hr	0.61	0.82	0.47	0.63
lb/ton	0.0027	0.0036	0.0021	0.0028
Total catch				
gr/DSCF	0.0041	0.0045	0.0031	0.0039
gr/ACF	0.0040	0.0043	0.0030	0.0038
lb/hr	0.91	0.98	0.64	0.84
lb/ton	0.0040	0.0043	0.0029	0.0037

(1) Throughput through primary crusher.

Reference 6.

TABLE 37

FACILITY D2

Summary of Visible Emissions[1]

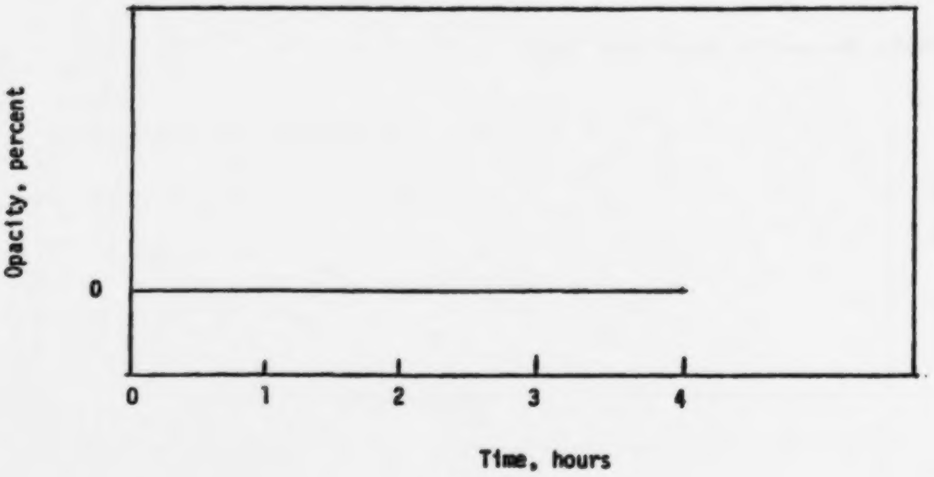
Date: 9/18/74	
Type of Plant: Crushed Stone - Finishing Screens	
Type of Discharge: Stack	Distance from Observer to Discharge Point: 300 ft
Location of Discharge: Baghouse	Height of Observation Point: 40 ft.
Height of Point of Discharge: 55 ft.	Direction of Observer from Discharge Point: North
Description of Background: Trees	
Description of Sky: Clear	
Wind Direction: Northerly	Wind Velocity: 5 to 10 mi/hr.
Color of Plume: None	Detached Plume: No
Duration of Observation: 240 minutes	

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set Number	Start	End	Sum	Average
1 through 40	8:30	12:30	0	0

Readings were 0 percent opacity during period of observation.

Sketch Showing How Opacity Varied with Time:



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[1] Two observers made simultaneous readings.

Reference 6.

TABLE 38

FACILITY D2

SUMMARY OF VISIBLE EMISSIONS (1)

Date: 7/10/75-7/11/75

Type of Plant: Crushed stone (Traprock)

Type of Discharge: Fugitive

Location of Discharge: Finishing screen

Height of Point of Discharge: 30-50 ft.

Distance from Observer to Discharge Point: 75 ft.

Description of Background: Equipment

Height of Observation Point: Ground level

Description of Sky: Partly cloudy

Direction of Observer from Discharge Point: Southwest

Wind Direction: Southwest

Wind Velocity: 0-5 mph

Color of Plume: White

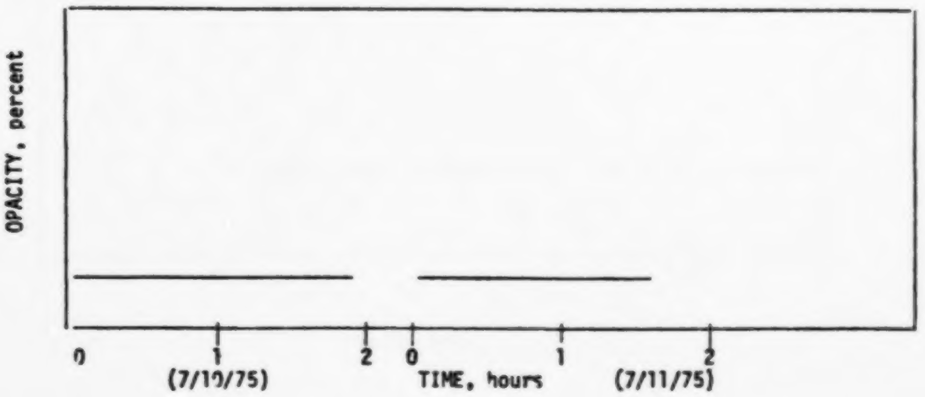
Detached Plume: No

Duration of Observation: 7/10/75 - observer 1 (94 minutes) - observer 2 (110 minutes)
7/11/75 - observer 1 (70 minutes) - observer 2 (100 minutes)

Summary of Data:

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	0	0	55	-	-
10	-	-	60	-	-
15	-	-	65	-	-
20	-	-	70	-	-
25	-	-	75	-	-
30	-	-	80	-	-
35	-	-	85	-	-
40	-	-	90	-	-
45	-	-	95	-	-
50	-	-	100	-	-

Sketch Showing How Opacity Varied With Time:



(1) Two observers made simultaneous readings.

Reference 7.

TABLE 39
FACILITY E1
Summary of Results

Run Number	1	2	3	Average
Date	11/18/74	11/18/74	11/19/74	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH(1)	384	342	460	395
Stack Effluent				
Flow rate - ACFM	15272	13997	14975	14748
Flow rate - DSCFM	16297	14796	15642	15578
Temperature - °F	33.1	40.4	41.0	38.2
Water vapor - Vol. %	0.5	0.0	0.5	0.3
Visible Emissions at Collector Discharge - % Opacity	SEE TABLE 40			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0134	0.0116	0.0147	0.0132
gr/ACF	0.0143	0.0122	0.0154	0.0140
lb/hr	1.87	1.47	1.97	1.77
lb/ton	0.0049	0.0043	0.0043	0.0045
Total catch				
gr/DSCF	0.0170	0.0137	0.0164	0.0157
gr/ACF	0.0181	0.0145	0.0171	0.0166
lb/hr	2.37	1.74	2.20	2.10
lb/ton	0.0067	0.0051	0.0048	0.0055

(1) Throughput through primary crusher.

Reference 8.

TABLE 40
FACILITY E1
Summary of Visible Emissions(1)

Date: 11/18/74 - 11/19/74

Type of Plant: Crushed Stone - Tertiary Crushing and Screening

Type of Discharge: Stack

Distance from Observer to Discharge Point: 60 ft.

Location of Discharge: Bagnouse

Height of Observation Point: Ground level

Height of Point of Discharge: 1/2 ft.

Direction of Observer from Discharge Point: South

Description of Background: Grey Wall

Description of Sky: Overcast

Wind Direction: Westerly

Wind Velocity: 2 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

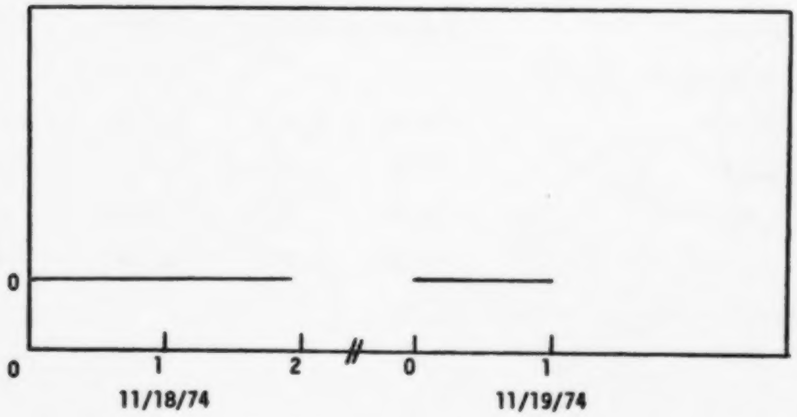
Duration of Observation: 11/18/74 - 120 minutes
11/19/74 - 60 minutes

SUMMARY OF AVERAGE OPACITY

Set Number	Time		Opacity	
	Start	End	Sum	Average
11/18/74				
1 through 10	9:00	10:00	0	0
11 through 20	10:15	11:15	0	0
11/19/74				
21 through 30	10:07	11:07	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time:



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(1) Two observers made simultaneous readings.

Reference 8.

TABLE 41

FACILITY E2

Summary of Results

Run Number	1	2	3	Average
Date	11/18/74	11/18/74	11/19/74	-
Test Time - Minutes	120	120	120	120
Production Rate - TPH(1)	384	342	460	395
Stack Effluent				
Flow rate - ACFM	22169	19772	21426	21122
Flow rate - DSCFM	23001	19930	21779	21570
Temperature - °F	44.5	59.2	55.0	52.9
Water vapor - Vol. %	1.1	1.1	0.6	0.9
Visible Emissions at Collector Discharge - % Opacity		SEE TABLE 42		
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.0132	0.0096	0.0153	0.0127
gr/ACF	0.0137	0.0097	0.0155	0.0130
lb/hr	2.60	1.65	2.85	2.37
lb/ton	0.0068	0.0048	0.0062	0.0059
Total catch				
gr/DSCF	0.0205	0.1378	0.0170	0.0171
gr/ACF	0.0213	0.0139	0.0173	0.0175
lb/hr	4.05	2.35	3.18	3.19
lb/ton	0.0105	0.0069	0.0069	0.0081

(1) Throughput through primary crusher.

Reference 8.

TABLE 42

FACILITY E2

Summary of Visible Emissions(1)

Date: 11/18/74 - 11/19/74

Type of Plant: Crushed Stone - Finishing Screens and Bins

Type of Discharge: Stack

Distance from Observer to Discharge Point: 120 ft

Location of Discharge: Baghouse

Height of Observation Point: Ground level

Height of Point of Discharge: 1/2 ft.

Direction of Observer from Discharge Point: South

Description of Background: Hillside

Description of Sky: Clear

Wind Direction: Westerly

Wind Velocity: 2 - 10 mi/hr.

Color of Plume: None

Detached Plume: No

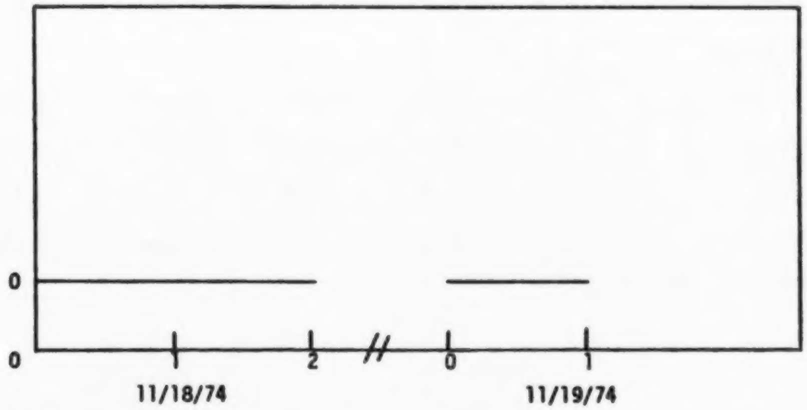
Duration of Observation: 11/18/74 - 120 minutes
11/19/74 - 60 minutes

SUMMARY OF AVERAGE OPACITY(2)

Set Number	Time Start	Time End	Opacity Sum	Opacity Average
11/18/74				
1 through 10	12:50	1:50	0	0
11 through 20	1:50	2:00	0	0
11/19/74				
21 through 30	9:05	10:05	0	0

Readings were 0 percent opacity during all periods of observation.

Sketch Showing How Opacity Varied With Time:



(1) Two observers made simultaneous readings.

Reference 8.

TABLE 43
FACILITY F
Summary of Results

Run Number	1	2	3	Average
Date	11/4/74	11/5/74	11/6/74	-
Test Time - Minutes	165	180	155	166
Drilling Rate - ft/hr	29.1	26.7	31.0	28.9
Stack Effluent				
Flow rate - ACFM	687	661	643	663
Flow rate - DSCFM	659	655	636	650
Temperature - °F	71.0	60.0	64.0	65.0
Water vapor - Vol. %	0.98	0.61	0.71	0.77
Visible Emissions at Collector Discharge - % Opacity	SEE TABLES 44 - 45			
Particulate Emissions				
Probe and filter catch				
gr/DSCF	0.032	0.031	0.055	0.039
gr/ACF	0.030	0.031	0.054	0.038
lb/hr	0.179	0.176	0.298	0.218
lb/CF of hole(1)	0.045	0.048	0.071	0.055
Total catch				
gr/DSCF	0.033	0.033	0.057	0.041
gr/ACF	0.032	0.032	0.056	0.040
lb/hr	0.189	0.183	0.308	0.227
lb/CF of hole	0.048	0.050	0.073	0.057

(1) Based on hole depth of 80 feet and hole diameter of 5 inches (0.136 ft^2).

Reference 10.

TABLE 44

FACILITY F

Summary of Visible Emissions

Date: 11/4/74 - 11/6/74

Type of Plant: Crushed Stone - Drill

Type of Discharge: Stack

Distance from Observer to Discharge Point: 10 ft.

Location of Discharge: Baghouse

Height of Observation Point: 6 ft.

Height of Point of Discharge: 10 ft.

Direction of Observer from Discharge Point: West

Description of Background: Quarry wall

Description of Sky: Partly cloudy

Wind Direction: Variable

Wind Velocity: 0 - 10 mi/hr.

Color of Plume: White

Detached Plume: No

Duration of Observation: 11/4/74 - 84 minutes
11/5/74 - 252 minutes
11/6/74 - 156 minutes

SUMMARY OF AVERAGE OPACITY

		Time		Opacity	
Date	Set Number	Start	End	Sum	Average
11/4/74	1 through 6	11:41	12:11	0	0
	7 through 15	12:20	1:14	0	0
11/5/74	16 through 21	8:07	8:43	0	0
	22 through 28	8:50	9:32	0	0
	29 through 35	10:14	10:56	0	0
	36 through 40	10:59	11:29	0	0
	41	11:29	11:35	5	0.2
	42	11:35	11:41	25	1.0
	43	11:41	11:47	45	1.9
	44	11:52	11:58	0	0
	45	12:04	12:10	30	1.2
	46	12:10	12:16	30	1.2
	47	12:16	12:22	55	2.3
	48	12:22	12:28	15	0.6
	49	12:28	12:34	55	2.3
	50	12:34	12:40	95	4.0
	51	12:39	12:45	5	0.2
	52	12:45	12:51	70	2.9
	53	12:51	12:57	65	2.7
	54	12:57	1:03	75	3.1
	55	1:03	1:09	65	2.7
	56	1:09	1:15	95	4.0
	57	1:15	1:21	75	3.1
11/6/74	58 through 63	7:59	8:35	0	0
	64 through 70	8:39	9:21	0	0
	71 through 76	9:28	10:04	0	0
	77 through 83	10:11	10:53	0	0

Readings ranged between 0 and 5 percent opacity during periods of observation.

Reference o

TABLE 45

FACILITY F

SUMMARY OF VISIBLE EMISSIONS(1)

Date: 7/2/75

Type of Plant: Crushed stone

Type of Discharge: Fugitive

Location of Discharge: Drill (Rotary)

Height of Point of Discharge: 2 feet

Distance from Observer to Discharge Point: 15 fee

Description of Background: Quarry wall

Height of Observation Point: Ground level

Description of Sky: Clear

Direction of Observer from Discharge Point: SE

Wind Direction: South

Wind Velocity: 0 - 5 mph

Color of Plume: White

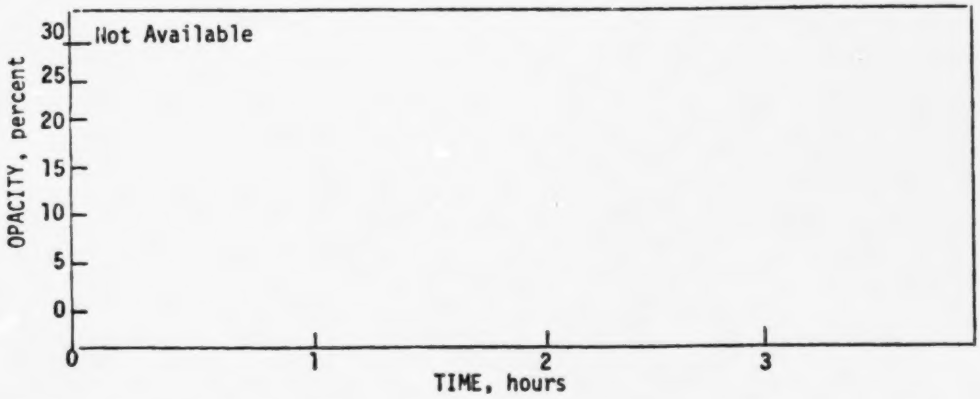
Detached Plume: No

Duration of Observation: 164 minutes

Summary of Data:(2)

Opacity, Percent	Total Time Equal to or Greater Than Given Opacity		Opacity, Percent	Total Time Equal to or Greater Than Given Opacity	
	Min.	Sec.		Min.	Sec.
5	152	0	55	-	-
10	140	45	60	-	-
15	103	30	65	-	-
20	38	45	70	-	-
25	3	15	75	-	-
30	0	15	80	-	-
35	0	0	85	-	-
40	-	-	90	-	-
45	-	-	95	-	-
50	-	-	100	-	-

Sketch Showing How Opacity Varied With Time:



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(1) Two observers made simultaneous readings, the greater of their readings is reported.

(2) No visible emissions were observed at the shroud used for capture. Readings reported above appeared at annular space between rotating drill rod and shroud collar.

Reference 4

TABLE 46
Facility G

Visible Emissions Data

Method 22

Test Point	Date	Observation Time (min)	Percent of Time Emissions Exceeded "X" Percent Opacity "X"	Observer 1	Observer 2
Primary Jaw Crusher	10/2/79	20	0	69	59
		40	10	26	44
Scalping Screen	10/3/79	60	15	67	69
Impact Crusher	10/4/79	20	0	78	96
		40	15	12	41
Final screen	10/3/79	60	0	0	0
Secondary Cone Crusher	10/2/79	120	10	76	61
Transfer Point	10/3/79	60	0	1	1

Reference 10

TABLE 47
Facility G
Summary of Visible Emissions
Method 9

Test Point	Date	Observation Time (min)	Percent of Time Emissions Greater than Given Opacity		
			Opacity (%)	Observer 1	Observer 2
Primary Jaw Crusher	10/2/79	100	0	89	89
			5	72	68
			10	32	35
			15	11	21
			20	3	12
			25	< 1	5
			30	< 1	1
			35	0	< 1
			40		0
Scalping Screen	10/3/79	60	0	100	100
			5	82	79
			10	19	15
			15	1	1
			20	0	0
Impact Crusher	10/4/79	60	0	100	100
			5	99	74
			10	29	17
			15	0	1
			20		0
Final Screens	10/3/79	60	0	1	0
			5	0	
Secondary Cone Crusher	10/2/79	120	0	93	85
			5	44	72
			10	11	58
			15	2	32
			20	< 1	14
			25	0	4
			30		< 1
			35		0
Transfer Point	10/3/79	60	0	3	--
			5	1	--
			10	1	--
			15	1	--
			20	1	--
			25	0	--

Reference 10

TABLE 48
Facility G
Summary of Visible Emissions
Method - Six Minute Averages

Date: 10/2/79 - 10/3/79

Set Number	Primary Crusher Observer 1	Primary Crusher Observer 2	Impact Crusher Screen Observer 1	Impact Crusher Screen Observer 2	Impact Crusher Observer 1	Impact Crusher Observer 2	Final Screen Observer 1	Final Screen Observer 2	Cone Crusher Observer 1	Cone Crusher Observer 2	Transfer Point Observer 1	Transfer Point Observer 2
1	9	13	10	11	15	10	0	0	4	11	3	--
2	7	1	8	10	11	7	0	0	5	18	0	--
3	14	6	9	8	11	7	0	0	8	22	0	--
4	14	15	8	9	11	9	0	0	11	25	0	--
5	13	11	8	10	11	10	0	0	9	23	0	--
6	14	13	12	9	10	8	0	0	10	17	0	--
7	12	9	13	9	10	13	0	0	9	16	0	--
8	--	10	12	10	11	13	0	0	7	15	0	-
9	7	14	10	10	13	10	0	0	10	15	0	-
10	9	10	10	11	11	9	0	0	8	16	0	--
11	2	15							8	15		
12	5	18							13	21		
13	15	21							7	13		
14	10	8							8	13		
15	10	10							8	15		
16	10	11							1	4		
17	10	5							0	1		
18									0	1		
19									0	1		
20									1	4		

Reference 10

TABLE 49
Facility H
Visible Emissions Data
Method 22

Test Point	Date	Observation Time (Min.)	"X"	Percent of Time Emissions Exceeded "X" Percent Opacity Observer 1	 2
Primary Jaw Crusher	10/11/79	30	0	27	27
		60	10	8	5
Scalping Screen	10/11/79	32	0	0	7
Secondary Screen	10/8/79	120	0	0	0
Secondary Cone Crusher	10/8/79	30	0	93	95
	10/10/79	21	15	87	72
Final Screens	10/8/79	120	0	0	0

Reference 10

TABLE 50
Facility H
Summary of Visible Emissions
Method 9

Test Point	Date	Observation Time (Min.)	Opacity (%)	Percent of Time Emissions Greater than Given Opacity Observer 1	2
Primary Jaw Crusher	10/11/79	90	0	23	73
			5	9	26
			10	3	13
			15	1	3
			20	< 1	2
			25	0	< 1
			30		< 1
			35		0
Scalping Screen	10/11/79	32	0	21	--
			5	0	--
Secondary Screen	10/8/79	120	0	0	18
			5		0
Secondary Cone Crusher	10/8/79 & 10/10/79	51	0	95	96
			5	95	95
			10	87	87
			15	45	58
			20	8	12
			25	0	0
Final Screen	10/8/79	120	0	0	< 1
			5		0

Reference 10

TABLE 51
Facility H
Summary of Visible Emissions
Method 9 - Six Minute Averages

Date: 10/8/79 - 10/11/79

Set Number	Primary Crusher Observer		Initial Screens Observer		Transfer Point Observer		Secondary Screens Observer		Cone Crusher Observer		Final Screens Observer	
	1	2	1	2	1	2	1	2	1	2	1	2
1	11	11	1	3	0	0	0	0	15	4	0	0
2	11	14	0	3	0	1	0	0	18	17	0	0
3	6	8	0	2	1	1	0	0	18	19	0	0
4	12	18	0	3	2	2	0	0	17	18	0	0
5	12	17	1	5	1	1	0	0	10	12	0	0
6	3	5	0	10	10	12	0	0	15	18	0	< 1
7	2	9	2	8	9	10	0	0	19	19	0	0
8	1	4	0	6	8	8	0	0	20	21	0	0
9	2	8	1	9	11	9	0	0	23	23	0	0
10	1	6	2	7	8	9	0	1	24	23	0	0
11	1	6	1	5	10	7	0	1	28	24	0	0
12	1	7	1	3	10	7	0	2	26	26	0	0
13	2	8	1	4	14	10	0	2	28*	28*	0	0
14	3	8	1	2	13	8	0	1	25	23	0	0
15	3	10	0	1	12	9	0	1	28	28	0	0
16	3	6	0	1	11	9	0	1	29	26	0	0
17	2	6	0	1	12	10	0	1	27**	26**	0	0
18	2	5	0	2	12	9	0	0	27	27	0	0
19	1	2	0	2	14	10	0	0	29	34	0	0
20	1	3	0	2	13	10	0	0	26	38	0	0
21									25**	39**		

* Four minute average
** Five minute average

Reference 10

Table 52
Facility I
Visible Emissions Data
Method 22

Test Point	Date	Observation Time (Min.)	"X"	Percent of Time Emissions Exceeded "X" Percent Opacity Observer 1	2
Scalping Screens	10/12/79	90	0	2	2
	10/15/79	30	0	2	4
Primary Jaw Crusher	10/15/79	30	0	93	92
		90	15	31	33
Conveyor Transfer Point	10/16/79	30	0	5	12
		30	10	3	30
Secondary Screen	10/16/79	90	0	4	9
		20	10	3	12
Secondary Cone Crusher	10/15/79	30	0	93	99
		90	15	7	< 1
Final Screens	10/15/79	120	0	0	0
Transfer Point	10/15/79	60	0	0	0
Transfer Point	10/16/79	60	0	2	2

Reference 10

TABLE 53
Facility I
Summary of Visible Emissions
Method 9

Test Point	Date	Observation Time (Min.)	Opacity (%)	Percent of Time Emissions Greater Than Given Opacity Observer 1	2
Scalping Screen	10/12/79	90	0	21	6
			5	0	1
			10		0
Primary Jaw Crusher	10/15/79	120	0	92	95
			5	70	86
			10	38	48
			15	21	15
			20	10	0
			25	2	
			30	0	
Transfer Point	10/16/79	60	0	27	42
			5	0	1
Secondary Screen	10/16/79	110	0	10	16
			5	0	0
Secondary Cone Crusher	10/15/79	120	0	99	100
			5	83	97
			10	29	64
			15	3	18
			20	0	0
Final Screens	10/15/79	120	0	1	< 1
			5	0	0
Transfer Point	10/15/79	60	0	0	0
Transfer Point	10/16/79	60	0	4	4
			5	1	2
			10	< 1	1
			15	0	< 1
			20		0

Reference 10

TABLE 54
Facility I
Summary of Visible Emissions
Method 9 - Six Minute Averages

Date: 10/12/79 - 10/16/79

	Initial Screens		Primary Crusher		Transfer Point		Secondary Screens		Cone Crusher		Final Screens		Transfer Point	
	Observer		Observer		Observer		Observer		Observer		Observer		Observer	
Run	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	< 1	0	14	13	0	0	0	0	< 1	8	0	0	0	0
2	0	0	16	14	0	1	< 1	3	9	14	0	0	0	0
3	2	0	16	14	2	1	< 1	1	9	17	<1	0	0	0
4	1	< 1	16	9	<1	< 1	0	0	12	15	1	< 1	0	0
5	3	1	12	13	0	0	0	0	13	15	0	0	0	0
6	1	< 1	9	15	1	3	0	0	11	15	0	0	0	0
7	1	0	13	14	2	4	0	0	13	16	0	0	0	0
8	1	0	9	14	<1	3	0	0	12	14	0	0	0	0
9	1	< 1	13	15	3	4	0	0	13	16	0	0	0	0
10	1	1	12	13	4	5	0	0	14	14	0	0	0	0
11	3	< 1	17	16			0	0	12	17	0	0	0	0
12	1	0	9	13			< 1	0	10	17	<1	0	0	0
13	< 1	< 1	14	11			4	0	9	17	0	0	0	0
14	< 1	1	13	12			5	0	7	10	0	0	0	0
15	< 1	< 1	15	13			0	0	8	15	<1	0	0	0
16	0	0	8	9			0	0	12	10	0	0	< 1	0
17	0	0	6	6			0	0	13	11	0	0	< 1	1
18	0	0	6	9			0	0	11	11	0	0	0	0
19	2	0	10	11			0	0	11	11	0	0	0	0
20	2	0	9	12			0	0	12	11	0	0	1	3

Reference 10

TABLE 55
Facility J
Visible Emissions Data
Method 22

Test Point	Date	Observation Time (Min.)	"X"	Percent of Time Emissions Exceeded "X" Percent Opacity Observer 1	2
Primary Jaw Crusher	10/25/79	60	0	3	5
		60	10	0	0
Scalping Screen	10/24/29	120	0	0	0
Secondary Cone Crusher	10/22/79	30	0	68	49
		30	10	8	14
		60	15	5	1
Secondary Screen	10/22/79	45	0	1	11
		75	0	1	6
Tertiary Cone Crusher	10/22/79	30	0	11	25
		30	10	37	36
		62	15	13	11
Transfer Point	10/23/79	120	0	0	< 1
Transfer Point	10/25/79	120	0	0	0

Reference 10

TABLE 56
Facility J
Summary of Visible Emissions
Method 9

Test Point	Date	Observer Time (Min.)	Opacity (%)	Percent of Time Emissions Greater Than Given Opacity Observer 1	2
Primary Jaw Crusher	10/25/79	120	0	21	21
			5	< 1	8
			10	0	< 1
			15		0
Scalping Screen	10/24/79	120	0	0	0
4.5' Cone Crusher	10/23/79	120	0	72	55
			5	5	1
			10	0	0
Secondary Screen	10/22/79	125	0	8	10
			5	0	< 1
			10		0
5.5' Cone Crusher	10/22/79	122	0	86	90
			5	62	70
			10	18	11
			15	0	0
Transfer Point	10/23/79	120	0	< 1	< 1
	& 10/24/79		5	0	0
Transfer Point	10/25/79	120	0	1	0
			5	0	

Reference 10

TABLE 57
Summary of Visible Emissions
Method 9 - Six Minute Averages

Date: 10/22/79 - 10/25/79

	Primary Crusher		Initial Screens		4½' Cone Crusher		Secondary Screens		5½' Cone Crusher		Transfer Point		Transfer Point	
	Observer		Observer		Observer		Observer		Observer		Observer		Observer	
Run	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1	3	1	0	0	3	3	4	2	2	0	0	0	0	0
2	1	2	0	0	4	4	3	0	0	2	0	0	0	0
3	1	1	0	0	4	5	0	0	3	5	0	0	0	0
4	1	0	0	0	2	3	0	0	5	5	0	0	0	0
5	1	1	0	0	4	3	0	0	4	4	0	0	0	0
6	1	3	0	0	6	4	0	0	6	9	0	0	0	0
7	1	1	0	0	6	4	0	0	11	9	0	0	0	0
8	1	1	0	0	3	2	0	0	10	10	0	0	0	0
9	0	2	0	0	2	2	0	0	11	10	0	0	0	0
10	1	2	0	0	5	3	0	0	13	10	0	0	0	0
11	1	1	0	0	4	3	0	0	11	11	0	0	0	0
12	0	0	0	0	5	5	0	0	11	10	0	0	0	0
13	0	0	0	0	3	2	0	0	12	15	0	0	0	0
14	0	1	0	0	5	4	0	0	8	9	0	0	0	0
15	2	2	0	0	5	3	0	0	10	12	0	0	0	0
16	1	0	0	0	5	2	0	0	12	12	0	0	0	0
17	3	2	0	0	3	0	0	0	5	10	0	0	0	0
18	3	3	0	0	3	2	0	0	6	9	0	0	0	0
19	2	1	0	0	3	1	0	0	5	11	0	0	0	0
20	0	1	0	0	1	2	0	0	5	9	0	0	0	0

Reference 10

TABLE 58
Facility K
Visible Emissions Data
Method 22

Test Point	Date	Observation Time (Min.)	"X"	Percent of Time Emissions Exceeded "X" Percent Opacity Observer	
				1	2
Primary Jaw Crusher	10/26/79	30	0	65	58
		60	10	9	11
		30	15	1	2
Transfer Point	10/26/79	90	0	2	1
	10/29/79	30	0	2	0
Scalping Screen	10/29/79	90	0	0	0
	10/30/79	30	0	0	0
Secondary Cone Crusher	10/29/79	30	0	100	100
	10/30/79	30	15	49	64
		60	20	10	5
Storage Bin	10/29/79	60	0	0	0
	10/30/79	60	0	0	0

Reference 10

TABLE 59
Facility K
Summary of Visible Emissions
Method 9

Test Point	Date	Observation Time (Min.)	Opacity (%)	Percent of Time Emissions Greater Than Given Opacity Observer	
				1	2
Primary Jaw Crusher	10/26/79	120	0	86	80
			5	43	33
			10	18	9
			15	8	3
			20	4	< 1
			25	2	0
			30	1	
			35	0	
Transfer Point	10/26/79	123	0	< 1	0
	& 10/29/79		5	0	
Scalping Screen	10/29/79	120	0	0	0
	& 10/30/79				
Secondary Cone Crusher	10/29/79	120	0	95	97
	& 10/30/79		5	84	88
			10	50	74
			15	17	54
			20	5	21
			25	0	1
			30		< 1
			35		0
Storage Bin	10/29/79	120	0	0	< 1
	& 10/30/79		5		0

Reference 10

TABLE 60
Facility K
Summary of Visible Emissions
Method 9 - Six Minute Averages

Date: 10/26/79 - 10/30/79

	Primary Crusher		Transfer Point		Initial Screens		Cone Crusher		Storage Bin	
	Observer		Observer		Observer		Observer		Observer	
Run	1	2	1	2	1	2	1	2	1	2
1	4	4	0	0	0	0	17	15	0	0
2	6	7	0	0	0	0	21	14	0	0
3	8	8	0	0	0	0	22	16	0	0
4	3	3	0	0	0	0	23	15	0	0
5	5	5	0	0	0	0	19	17	0	0
6	10	8	0	0	0	0	17	11	0	0
7	4	3	4	0	0	0	20	13	0	0
8	5	5	0	0	0	0	15	8	0	0
9	11	7	0	0	0	0	16	8	0	0
10	7	7	0	0	0	0	16	9	0	0
11	8	4	0	0	0	0	6	6	0	0
12	8	8	0	0	0	0	9	7	0	0
13	8	6	0	0	0	0	18	15	0	2
14	9	8	0	0	0	0	17	16	0	0
15	10	6	0	0	0	0	19	16	0	2
16	8	8	0	0	0	0	18	15	0	0
17	10	5	0	0	0	0	15	14	0	0
18	9	4	0	0	0	0	13	13	0	0
19	10	6	0	0	0	0	18	16	0	2
20	6	5	0	0	0	0	18	14	0	0

Reference 10

REFERENCES FOR APPENDIX A

1. Air Pollution Emission Test Report for Plant A, prepared jointly by EPA and Valentine, Fisher and Tomlinson Consulting Engineers, Contract No. 68-02-0236, Task 16, EPA Report No. 74-STN-1.
2. Davis, John, Trip Report of Visible Emission Tests at Plant A, July 22, 1975.
3. Air Pollution Emission Test Report for Plant B, prepared for EPA by Engineering-Science Incorporated, Contract No. 68-02-1406, Task 7, EPA Project Report No. 75-STN-3.
4. Brown, John W., Trip Report of Visible Emission Tests at Plants B and F, July 14, 1975.
5. Air Pollution Emission Test Report for Plant C, prepared for EPA by George D. Clayton and Associates, Contract No. 68-02-1408, Task 6, EPA Report No. 75-STN-7.
6. Source Testing Report for Plant D, prepared for EPA by Roy F. Weston Incorporated, Contract No. 68-02-0240, Task 10, EPA Report No. 75-STN-2.
7. Burbank, Jason J., Trip Report of Visible Emission Tests at Plant D, July 23, 1975.
8. Air Pollution Emission Test Report for Plant E, prepared for EPA by York Research Corporation, Contract No. 68-02-1401, Task 9, EPA Report No. 75-STN-6.
9. Air Pollution Emission Test Report for Plant F, prepared for EPA by Engineering-Science Incorporated, Contract No. 68-02-1406, Task 7, EPA Report No. 75-STN-4.
10. Air Pollution Emission Test Report for Plants G, H, I, J and K, prepared for EPA by Scott Environmental Services, Contract No. 68-02-2813, Tasks 39 and 40, January, 1980.

APPENDIX B

METHOD 22--VISUAL DETERMINATION OF FUGITIVE EMISSIONS FROM MATERIAL PROCESSING SOURCES

1. Introduction

This method involves the visual determination of fugitive emissions; i.e., emissions not emitted directly from a process stack or duct. Fugitive emissions include emissions that (1) escape capture by process equipment exhaust hoods, (2) are emitted during material transfer, (3) are emitted from buildings housing material processing or handling equipment, and (4) are emitted directly from process equipment.

This method determines the amount of time that any visible emissions occur during the observation period, i.e., the accumulated emission time. This method does not require that the opacity of emissions be determined. Since this procedure requires only the determination of whether a visible emission occurs and does not require the determination of opacity levels, observer certification according to the procedures of Reference Test Method 9 are not required. However, it is necessary that the observer is educated on the general procedures for determining the level of visible emissions. As a minimum the observer should be trained regarding the effects on the visibility of emissions caused by background contrast, ambient lighting, observer position relative to lighting, and the presence of uncombined water (condensing water vapor).

2. Applicability and Principle

2.1 Applicability. This method applies to the determination of the frequency of fugitive emissions from stationary sources (located indoors or outdoors) when specified as the test method for determining compliance with new source performance standards.

2.2 Principle. Fugitive emissions produced during material processing, handling, and transfer operations are visibly determined by an observer without the aid of instruments.

3. Definitions

3.1 Emission Frequency. Percentage of time that emissions are visible during the observation period.

3.2 Emission Time. Accumulated amount of time that emissions are visible during the observation period.

3.3 Fugitive Emission. Pollutant generated by an affected facility that is not collected by a capture system and is released to the atmosphere.

3.4 Observation Period. Accumulated time period during which observations are conducted, not to be less than 6 minutes.

4. Equipment

4.1 Stopwatches. accumulative type, with a sweep second hand and unit divisions of at least 0.5 second; two required.

4.2 Light Meter. Light meter capable of measuring illuminance in the 50- to 200-lux range; required for indoor observations only.

5. Procedure

5.1 Position. Survey the affected facility or building or structure housing the process unit to be observed, and determine the locations of potential emissions. If the affected facility is located inside a building, determine an observation location that is consistent with the requirements of the applicable regulation (i.e., outside observation of emissions escaping the building/structure or inside observation of emissions directly emitted from the affected facility process unit.)

Then select a position that enables a clear view of the potential emission point(s) of the affected facility or of the building or structure housing the affected facility, as appropriate for the applicable subpart. A position of at least 15 feet but not more than 0.25 mile from the emission source is recommended. For outdoor locations, select a position where the sun is not directly in the observer's eyes.

5.2 Field Records

5.2.1 Outdoor Location. Record the following information on the field data sheet (Figure 22-1): company name, industry, process unit, observer's name, observer's affiliation, and date. Record also the estimated wind speed, wind direction, and sky condition. Sketch the process unit being observed, and note observer location relative to the source and the sun. Indicate the potential and actual fugitive emission points on the sketch.

5.2.2 Indoor Location. Record the following information on the field data sheet (Figure 22-2): company name, industry, process unit, observer's name, observer's affiliation, and date. Record, as appropriate, the type, location, and intensity of lighting on the data sheet. Sketch the process unit being observed, and note observer location relative to the source. Indicate the potential and actual fugitive emission points on the sketch.

5.3 Indoor Lighting Requirements. For indoor locations, use a light meter to measure the level of illumination at a location as close to the emission source(s) as is feasible. An illumination of greater than 100 lux (10 foot candles) is considered necessary for proper application of this method.

5.4 Observations. Record the clock time when observations begin. Use one stopwatch to monitor the duration of the observation period; start this stopwatch when the observation period begins. If the observation period is divided into two or more segments by process shutdowns or observer rest breaks, stop the stopwatch when a break begins and restart it without resetting when the break ends. Stop the stopwatch at the end of the observation period. The accumulated time indicated by this stopwatch is the duration of the observation period. When the observation period is completed, record the clock time.

During the observation period, continuously watch the emission source. Upon observing an emission (condensed water vapor is not considered an emission), start the second accumulative stopwatch; stop the watch when the emission stops. Continue this procedure for the entire observation period. The accumulated elapsed time on this stopwatch is the total time emissions were visible during the observation period, i.e., the emission time.

5.4.1 Observation Period. Choose an observation period of sufficient length to meet the requirements for determining compliance with the emission regulation in the applicable subpart. When the length of the observation period is specifically stated in the applicable subpart, it may not be necessary to observe the source for this entire period if the emission time required to indicate non-compliance (based on the specified observation period) is observed in a shorter time period. In other words if the regulation prohibits emissions for more than 6 minutes in any hour, then observations may (optional) be stopped after an emission time of 6 minutes is exceeded. Similarly, when the regulation is expressed as an emission frequency and the regulation prohibits emissions for greater than 10 percent of the time in any hour, then observations may (optional) be terminated after 6 minutes of emissions are observed since 6 minutes is 10 percent of an hour. In any case, the observation period shall not be less than 6 minutes in duration. In some cases, the process operation may be intermittent or cyclic. In such cases, it may be convenient for the observation period to coincide with the length of the process cycle.

5.4.2 Observer Rest Breaks. Do not observe emissions continuously for a period of more than 15 to 20 minutes without taking a rest break. For sources requiring observation periods of greater than 20 minutes, the observer shall take a break of not less than 5 minutes and not more than 10 minutes after every

15 to 20 minutes of observation. If continuous observations are desired for extended time periods, two observers can alternate between making observations and taking breaks.

5.5 Recording Observations. Record the accumulated time of the observation period on the data sheet as the observation period duration. Record the accumulated time emissions were observed on the data sheet as the emission time. Record the clock time the observation period began and ended, as well as the clock time any observer breaks began and ended.

6. Calculations

If the applicable subpart requires that the emission rate be expressed as an emission frequency (in percent), determine this value as follows: Divide the accumulated emission time (in seconds) by the duration of the observation period (in seconds) or by any minimum observation period required in the applicable subpart if the actual observation period is less than the required period, and multiply this quotient by 100.

FUGITIVE EMISSION INSPECTION
OUTDOOR LOCATION

Company ______________________

Location ______________________

Company representative ______________________

Observer ______________________

Affiliation ______________________

Date ______________________

Sky conditions ______________________

Precipitation ______________________

Wind direction ______________________

Wind speed ______________________

Industry ______________________

Process unit ______________________

Sketch process unit; indicate observer position relative to source and sun; indicate potential emission points and/or actual emission points.

OBSERVATIONS

	Clock time	Observation period duration, min:sec	Accumulated emission time, min:sec
Begin observation	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
	________		
		________	________
End observation	________		

Figure 22-1